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THE EFFECTS OF CHRONIC AND SINGLE NUTRIENT INPUTS ON FIRST YEAR FALLOW VEGETATION IN MICHIGAN

By

Frank C. P. Reed III

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ABSTRACT

THE EFFECTS OF CHRONIC AND SINGLE NUTRIENT INPUTS ON FIRST YEAR FALLOW VEGETATION IN MICHIGAN

By

Frank C. P. Reed III

The response of first year fallow field vegetation to fertilization with 10-20-0 (NPK) fertilizer under different schedules was studied on the Michigan State University campus in 1972. A 4x4 Latin Square design was used and treatments were as follows: checks; 450 $kg \cdot N \cdot ha^{-1}$ applied once; 45 $kg \cdot N \cdot ha^{-1}$ applied weekly ten times; and 90 $kg \cdot N \cdot ha^{-1}$ applied biweekly five times. The response of the plant community was measured in terms of changes through the season in species composition, community diversity, net annual above ground primary production, below ground production and nutrient accumulation by above gound plant material. Changes in soil nitrogen (Kjeldahl) and nitrate were monitored in all treatments through the growing season.

Results showed that fertilization, using any of the schedules in this study, increased net annual above ground production about 50 percent. Underground production in all treatments was statistically similar in September. Nutrient accumulation by above ground plant material showed that fertilized vegetation reclaimed about 45 percent of the nitrogen applied. Diversity showed no significant response to any of the treatments. The number of plant species present decreased significantly in

fertilized plots. This effect was most pronounced in the single fertilizer application. Soil nitrogen showed no pattern of change across the season in any of the treatments. Soil nitrate nitrogen decreased in checks and increased in other treatments over the season. The implications of this are discussed in terms of the relationship of the number of species and production within a season.

The results indicate that the number of species and production tend to be negatively correlated in these plant arrays over the season. The possible cause of this is discussed.

The species of plants composing the experimental plant arrays are discussed in reference to their biochemical pathway of carbon fixation and their performance as accumulators of nitrogen under fertilization.

Finally, general considerations for the operation of a waste water renovation area are discussed in reference to the soil-plant system and its behavior.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES --- Continued

LIST OF FIGURES

INTRODUCTION

The increasing human population, its trend toward centralization and geographic concentration, and increasing rates of material consumption pose a major problem to society--that of waste disposal. The employment of natural and managed (crop) ecosystems in processing the bioactive elements of domestic waste has been suggested as an alternative to traditional dilution-transport waste disposal methods (Sopper, 1971). Indeed, many industrial and domestic operations are presently utilizing natural or crop ecosystems to process (dispose of) bioactive wastes (see Law, 1968; Sopper, 1971).

It is becoming increasingly apparent that acceptable and effective means of waste processing by natural vegetation or crop arrays must incorporate the essential features of natural nutrient cycling. In addition, one must consider the impact nutrient rich wastes will have on the properties of natural vegetation. It is imperative that we determine both the long and short range effects of wastes on those properties of natural communities which make them attractive for waste processing. Diverse systems are viewed as more stable than simple systems (Loucks, 1970; MacArthur, 1972) due to greater spatial and temporal distribution of processes. In diverse communities, individual plant populations display active growth phases that are temporally spaced, giving the system an active period greater than that in a monoculture. It is the control and utilization of these populations which is important in the operation of an effective spray irrigation program for the distribution of effluents.

Ecologists have long debated the relationships that appear to exist between diversity, productivity, dominance and stability of natural ecosystems exemplified in papers by (Connell and Orias, 1964; Leigh, 1965; Golley and Gentry, 1966; Monk, 1967; McNaughton, 1968; Margalef, 1968, 1969; Cooke et al., 1968; Singh and Misra, 1969; Whittaker, 1969; Loucks, 1970; Hurd et al., 1971; Daubenmire, 1972; Stephenson, 1973a), but to date no concensus has been reached. Most debators have viewed these community properties in relation to succession. Recent studies (Golley and Gentry, 1966; Hurd et al., 1971; Hall et al., 1971; Stephenson, 1973a) have attempted to examine community organization as it is affected by nutrient augmentation. With the exception of the study of Hall et al. (1971) these studies have used low levels of nutrients in single applications.

Other studies, most notably the studies at Hubbard Brook (Likens et al., 1967; Bormann et al., 1968; Likens et al., 1970), have examined nutrient cycling in whole communities by removing the vegetation to determine its role. Here, however, I am dealing with nutrient cycling in a community that has been fertilized.

The use of crop systems has been suggested (Sopper, 1971) for use in effluent spray irrigation systems. However, crop systems have some limitations, one of which is the completely synchronous active growing period of the vegetation. Agronomists (Adriano et al., 1972a, 1972b) have described the nitrogen movement and balance in row crop systems with an interest in the uptake and leaching of nitrogen in reference to the amount applied in fertilizer. However, this type of system requires high maintenance through the addition of herbicides and insecticides to prevent damage to the crop. These systems are sometimes over fertilized; this results in the crop being less efficient in reclaiming applied nutrient. The unreclaimed balance is either retained by or passes through the system. Another characteristic of crop (monoculture) systems, pointed out by Root (1973), is that with the total biomass of an area concentrated into one type of vegetation they are more susceptible to high levels of herbivory. This leads to the conclusions that less diverse systems would also be open to more herbivory. Less diverse systems with the majority of biomass concentrated in one or two species would presumably be more open to attacks from disease organisms. In short, less diverse systems seem more unstable, in the sense of being susceptible to catastrophic disruption of community processes.

To date I know of no studies which have attempted to evaluate the impact of fertilizer on the total plant-soil relationships of natural communities. This study is an initial attempt at comparing the effects of chronic and single application inputs on the organization and processing ability of a first year fallow community. Although water itself will play a major role in processing ability, it was unavailable and only fertilizer was used in this study to simulate domestic waste, using levels of nitrogen (Total N ranging to 30 ppm.; NO_3-N ranging to 5.0 ppm.; organic and ammonium N ranging to 25.0 ppm.) presently found in secondary effluent from the East Lansing waste treatment plant as a guideline to establish amounts of fertilizer applied. The concentration of nutrient applied to the system is approximately three times that which would be contributed in effluent applied at two inches per acre per week if applied over a period of ten weeks and equal to the amount that would be applied in an application period of 30 weeks. However, concentrations of nutrients in these and other wastes may rise, at least those of nitrogen. Also, the application period for spray irrigation may have to be shortened to take advantage of plants' growing season. Due to a shortened application period the concentration of nitrogen in the waste may have to be raised by some preprocessing to a level equal to that applied in this study. In this study the fertilizer was applied over a period of ten weeks.

The utility of this research is that it has both applied and basic aspects. Relative to the former aspect, this research identifies some plants that accumulate high percentages of nitrogen, describes the biomass accumulated in vegetation through the season, and describes nitrate behavior in soil receiving fertilizer application under different schedules. In the basic sense this research examines the interaction of plants and soil in relation to the ecological phenomena of diversity and primary production.

METHODS AND MATERIALS

Experimental Site

The study area is located on the South campus of Michigan State University (T3N, R1W, S6), in Ingham County Michigan (Dept. of Conservation Maps, 1965). The experimental site is generally level and includes two soil types, Miami and Conover loam, both possessing low water permeability and high phosphorous adsorption capacity (Schneider and Erickson, 1972). The site had been abandoned from corn for about six years prior to site preparation and was dominated by perennial herbs (*Agropyron repens*, *Taraxacum officinale*, *Solidago* spp.).

Site Preparation

On May 12, 1972, sixteen random samples of one-quarter square meter each were selected on the site and all material above ground was harvested, placed in plastic bags and transported to the laboratory. Both living material and litter were separated into monocot and dicot and treated as described in the section on above ground biomass. This was done to ascertain the amount of biomass and nutrient to be plowed under. On May 16, 1972, the site was plowed and disced in preparation for experimentation.

Design and Treatment

The experimental design utilized four treatment categories arranged in a 4x4 Latin Square (Figure 1). Blocks were 10x10 meters, each separated

FIGURE 1.

Field Design

A - Control 0 $Kg \cdot N \cdot ha^{-1} \cdot wk^{-1}$

B - 45 $Kg \cdot N \cdot ha^{-1}$ (over 10 weeks - weekly)

C - 90 $Kg \cdot N \cdot ha^{-1}$ (biweekly over 10 weeks)

D - 450 $Kg \cdot N \cdot ha^{-1}$ (one application)

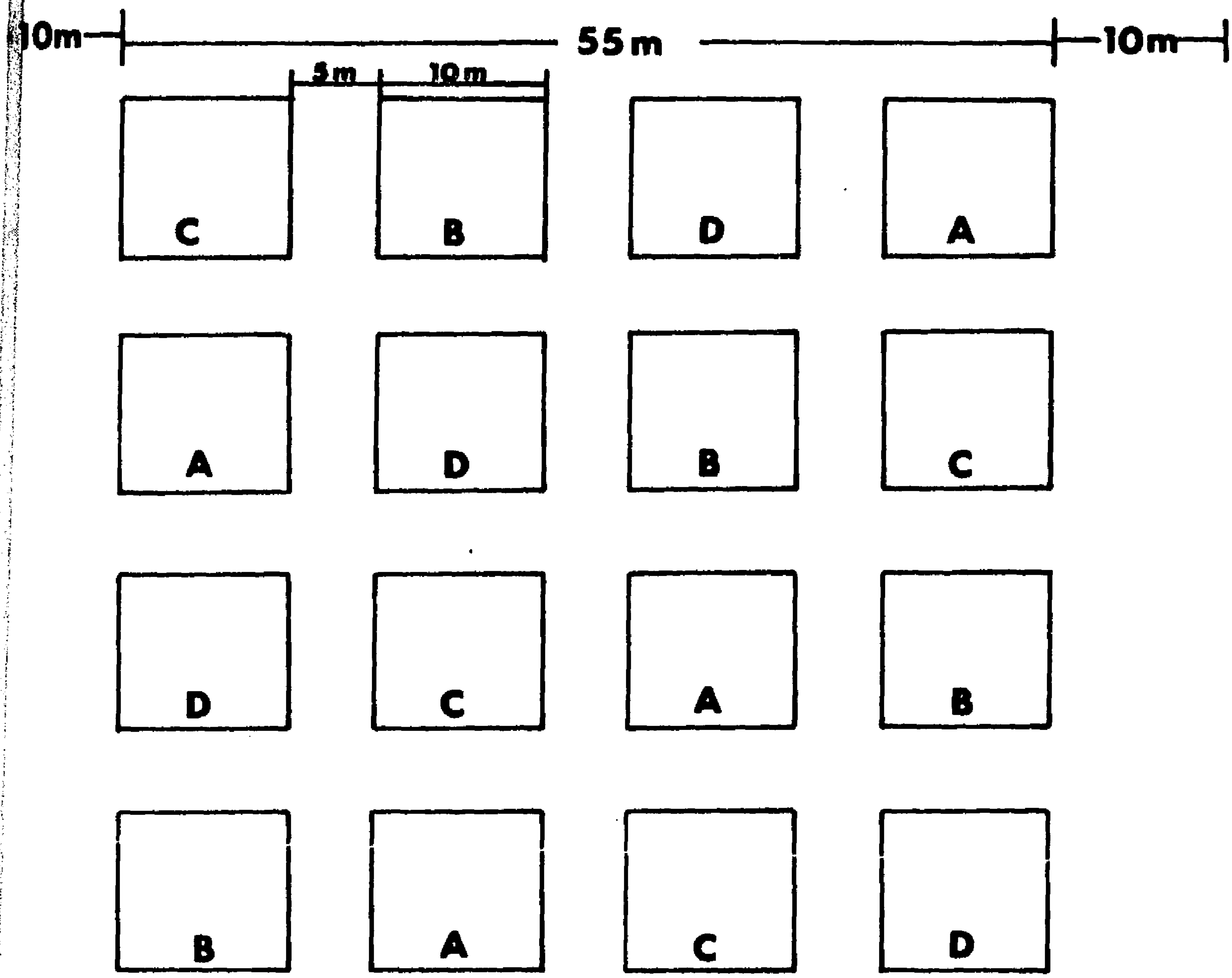

Figure 1.

from adjacent blocks by buffer strips of four meters. Treatments were randomly allocated once per row and once per column as specified by the design. Treatments consisted of the following amounts of 10-20-0 (NPK) fertilizer: one (1)-check; two (2)- 450 $kg \cdot N \cdot ha^{-1}$ applied once; three (3)- 45 $kg \cdot N \cdot ha^{-1}$ applied weekly for ten weeks; four (4)- 90 $kg \cdot N \cdot ha^{-1}$ applied biweekly five times. Fertilizer was of the pebble type with nitrogen in the form of NH_4NO_3 and phosphorus as a mixture of soluble phosphates. Fertilizer applications were made by hand beginning on June 1, and continuing until August 3, 1972. Uniformity of fertilizer application was attempted by distributing the fertilizer as one handful of fertilizer per pace. This pacing was done five times in a north-south and five times in an east-west direction in each block. To check this ten containers with a diameter of 12 cm. each were randomly placed in a plot receiving 4.5 kg. of fertilizer. The mean amount of fertilizer per pot was 3.35 grams, the largest being 4.5 grams and the smallest 1.5 grams. This compares to a calculated amount of 4.0 grams that should have been present in each container.

Data Collection

Above Ground Biomass

Above ground plant biomass was sampled monthly commencing in July and ending in October. Four randomly selected one-quarter square meter samples were harvested in each block at each sampling date. No subsequent samples were taken on previously sampled sites nor were any sites used that bordered on previously sampled sites.

Materials were clipped at ground level, placed in labelled plastic bags for transport to the laboratory and stored at near $0^{\circ}C$ until processing.

Each sample was weighed, separated by species, placed in a forced air drying oven at 100°C for a period not less than twenty-four hours, re-weighed and the dry weight recorded by species. Nomenclature follows Gleason (1968).

Below Ground Biomass

A minimum of eight randomly selected individual plants of the five most common annual species (*Amaranthus retroflexus*, *Chenopodium album*, *Ambrosia artemisiifolia*, *Polygonum pensylvanicum*, *Setaria glauca*) were harvested in July, August and September. *Sonchus asper*, a perennial, was harvested as rhizome and all attached above ground parts in July and August. Roots and rhizomes of *Agropyron repens* were obtained in July, August, September and October from soil blocks ten by ten centimeters to a depth of twenty centimeters. All material was placed in labelled plastic bags and transported to the laboratory. The below ground material was cleared of soil particles using the method of Pavlychenko (1937) and separated from the above ground material. The cleared material was oven dried at 100°C for twenty-four hours and the dry weight recorded. Data concerning *Solidago* spp. was provided by S. N. Stephenson (unpublished data). Linear regression equations were developed to describe the ratio of above to below ground biomass. Since no difference was noted when annual plants were treated separately by treatment or combined from all treatments, the latter was used in this study. Since *Agropyron* did show a difference when treated separately by treatment and *Sonchus* did not, *Agropyron* was treated separately by treatment and *Sonchus* was combined when linear regression equations were developed.

Soils

Soil samples were taken monthly in each block from June to October. Cores were removed to a depth of 1 meter in each block from quadrats previously used for vegetation samples. Each core was divided into ten sections of ten centimeters each. In June and July two samples per block were composited while in August, September and October single samples were taken due to difficulty of sampling. Each ten centimeter core segment was placed in a plastic bag, transported to the laboratory and weighed to determine the wet weight. Each sample was then oven dried at 72°C for a minimum of forty-eight hours, removed and dry weight recorded. This material was then stored in labelled, sealed containers.

Nutrient Analysis

Plant

All dried plant material harvested as above ground biomass was treated as follows. All dry plant material of each species in each block was combined. If the weight exceeded ten grams dry weight the material was completely ground in a Wiley Mill to pass a 50 mesh screen. Subsamples of ground material of each species in each block were further ground to pass a 20 mesh screen. This material was analyzed for total nitrogen using the Kjeldahl method.*

Soil

All dried soil samples were milled and analyzed for total nitrogen using the Kjeldahl method. Nitrate nitrogen was evaluated by mixing together 20 grams of soil with 50 ml. of $CaSO_4$ solution (20 grams $CaSO_4 \cdot 2H_2O$).

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*Analysis was conducted in the laboratory of Dr. A. L. Kenworthy of the Horticulture Department at Michigan State University.

This material was shaken for thirty minutes and nitrate concentration determined using an Orion Model 801 ion meter.

Analyses

Diversity

Diversity was calculated using the Shannon-Weaver formulation (Pielou, 1969)

$$H'_{com} = -\Sigma p_i \log_2 p_i$$

where $\underline{p}$ is the proportion of the i^{th} species. Diversity within each block (community) was calculated using the summed above ground biomass from the four samples in each block. Diversity within treatments ($\bar{H}'_{com}$) was calculated with a mean and standard error of the four replicates in each treatment.

Evenness

The evenness component of diveristy was calculated using the formulation (Pielou, 1969)

$$J'_{com} = \frac{H'_{com}}{H'_{max}}$$

where H'_{max} is the maximum diversity that can be attained by the number of species present. As before, J'_{com} within blocks was calculated from summed above ground biomass data of the four samples within a block. Evenness within treatments ($\bar{J}'_{com}$) was calculated with a mean and standard error of the four replicates.

Nutrient Accumulation

Within a block the estimated above ground biomass per square meter of each species was multiplied by the nitrogen content of that species and summed for all species in that block. Blocks within treatments were combined and a mean and standard error of nutrient accumulation determined on a treatment basis. This was converted to a kilogram per hectare basis.

Production

Above and below ground production on each sampling date was determined for each treatment by summing the dry weight of each species in each block and combining blocks within a treatment to derive a mean and standard error for the treatment. For the below ground production, plants that appeared structurally similar to those harvested for determination were treated similarly, that is, the same regression equation was applied to them as to the sample species (Table A21). All species not included in this table with the exception of *Solidago* spp. contributed only minute quantities of below ground material. Peak community production was determined by combining the peak above ground production of each species in a block and combining blocks to derive an estimate of peak community production in each treatment.

Soil Analysis

Both total nitrogen (as a percent per gram of soil) and nitrate nitrogen (ppm.) present in the soil in each ten centimeter increment was determined at each time interval for each treatment using data from the four replicate blocks in each treatment.

Statistical Comparisons

All data in tables that represent a mean of the four replicates in each treatment were tested for significant differences using Tukey's w-procedure, henceforth referred to as LSR (Sokal and Rohlf, 1969), where

$$LSR = Q_{\alpha(k,v)}\sqrt{\frac{\text{MS within}}{n}}$$

and in this study $n = 4$, $k = 4$, and $v = 6$. The mean square within (error mean square) was derived using Analysis of Variance for the Latin Square Design. A prototype of the Latin Square analysis is given in Table 1.

Table 1. Prototype AOV for Latin Square design used in this study.

Source	df	MS	F
Rows	3	x	$\frac{x}{a}$
Columns	3	y	$\frac{y}{a}$
Treatments	3	z	$\frac{z}{a}$
Error	6	a	
Total	15		

RESULTS

The major species contributing the bulk of the biomass in all treatments were: Agropyron repens, Amaranthus retroflexus, Setaria spp., Chenopodium album, and Polygonum pensylvanicum. Annuals dominated in July and early August in the check communities, but by the end of the season Agropyron, a perennial, dominated. In the treatment blocks annuals dominated the system throughout the season probably due to their rapid response to increased nutrient. Species recorded in the experimental area are indicated in Table 2, along with their biochemical pathway of carbon fixation which will be discussed later in reference to this study.

Analysis of Variance for the Latin Square design was performed to test for treatment effect on above ground biomass, Shannon-Weaver diversity, evenness, number of species and estimated below ground biomass. Significant differences ($p \leq 0.05$) were noted in above ground biomass due to treatment at all sampling dates (Table 3). Shannon-Weaver diversity showed an overall effect of treatment only in August (Table 4). Number of species showed a treatment effect in August, September and October (Table 5). Evenness showed no treatment effect at any sampling date. Estimated below ground biomass showed a treatment effect in July and August but not in September or October (Table 6).

Diversity, calculated from biomass data (Tables A1-16) at each sample date for each treatment is presented in Table 7. Using the LSR test, no significant differences in Shannon-Weaver diversity were noted

Table 2. Species present in experimental area: biochemical pathway - C_3 or C_4.

Species	C_3	C_4
Acalypha spp.	X	
Agropyron repens	X	
Amaranthus alba		X
Amaranthus retroflexus		X
Ambrosia artemisiifolia	X	
Aster spp.	X	
Barbarea vulgaris	X	
Berteroa incarna	X	
Capsella bursa-pastoris	X	
Chenopodium album	X	
Cirsium vulgare	X	
Cyperus esculentus		X
Caucus carrota	X	
Digitaria sanguinalis		X
Echinochloa crusgalli		X
Erigeron annuus	X	
Euphorbia maculata		X
Glyceria spp.	X	
Hieracium spp.	X	
Juncus spp.	X	
Lepidium campestre	X	
Lychnis alba	X	
Malva spp.	X	
Medicago sativa	X	
Medicago lupilina	X	
Melilotus officinalis	X	
Moss	X	
Osalis stricta	X	
Panicum capillare		X
Panicum dichotomiflorum		X
Panicum spp.		X
Phalaris arundinacea	X	
Phleum pratense	X	
Physalis spp.	X	
Plantago lanceolata	X	
Plantago rugelli	X	
Poa compressa	X	
Polygonum aviculare	X	
Polygonum convolvulus	X	
Polygonum pensylvanicum	X	
Polygonum persicaria	X	
Portulaca oleracea		
Rumex crispus	X	
Setaria glauca		X
Setaria viridis		X

Table 2. Species present in experimental area; biochemical pathway - C_3 or C_4.

Species	C_3	C_4
Solanum nigrum	X	
Solidago canadensis	X	
Solidago graminifolia	X	
Sonchus asper	X	
Stellaria media	X	
Taraxacum officinale	X	
Thlaspi arvense	X	
Trifolium pratense	X	
Trifolium repens	X	
Urtica spp.	X	
Verbascum blattaria	X	
Unknown		

Table 3. AOV analysis for Latin Square design of above ground biomass production from four replicates of each treatment at each time period. F_T is the F ratio for treatment.

Source	df	SS_{July}	SS_{August}	$SS_{September}$	$SS_{October}$
Row	3	36057.1	229339.1	246923.9	162813.1
Column	3	16315.2	12911.3	89788.9	28447.1
Treatment	3	53046.2	168328.5	522944.2	218474.7
Error	6	20384.3	36120.0	43623.6	41171.1

$F_{.05(3,6)} = 4.76$ $F_T = 5.20$ $F_T = 9.32$ $F_T = 23.98$ $F_T = 10.61$

Table 4. Analysis of Variance for a Latin Square design of Shannon-Weaver diversity index from four replicates of each treatment at each time period. F_T is the F ratio for treatment.

Source	df	SS_{July}	SS_{August}	$SS_{September}$	$SS_{October}$
Row	3	2.265	0.161	0.697	0.213
Column	3	0.933	1.133	1.154	1.128
Treatment	3	0.645	1.072	0.783	0.884
Error	6	0.520	0.429	1.909	1.214
$F_{.05(3,6)} = 4.76$		$F_T = 2.48$	$F_T = 5.03$	$F_T = 0.82$	$F_T = 1.46$

Table 5. AOV analysis for the Latin Square design of the number of plant species present using four replicates of each treatment at each time period. F_T is the F ratio for treatment.

Source	df	SS_{July}	SS_{August}	$SS_{September}$	$SS_{October}$
Row	3	13.19	10.25	3.25	60.19
Column	3	32.69	43.25	72.25	38.19
Treatment	3	44.69	131.25	158.75	311.19
Error	6	42.38	5.0	53.5	60.88
$F_{.05(3,6)} = 4.76$		$F_T = 2.11$	$F_T = 52.5$	$F_T = 5.93$	$F_T = 10.22$

Table 6. AOV analysis for Latin Square design using estimated underground biomass from four replicates of each treatment at each time period. F_T is the F ratio for treatment.

Source	df	SS_{July}	SS_{August}	$SS_{September}$	$SS_{October}$
Row	3	20907.78	9111.14	12951.30	6476.97
Column	3	6339.02	7190.58	5483.09	26647.69
Treatment	3	79580.28	62433.55	1099.90	40067.53
Error	6	3236.92	14036.78	10085.59	20549.41
$F_{.05(3,6)} = 4.76$		$F_T = 49.17$	$F_T = 8.90$	$F_T = 0.22$	$F_T = 3.90$

Table 7. Diversity ($\bar{X} \pm SE$) in each treatment over time. Values were derived from four replicates in each treatment.

Treatment	July[1]	August	September	October
Check	2.78 ± 0.37	2.70 ± 0.21	2.58 ± 0.22	2.32 ± 0.18
Single	2.42 ± 0.26	2.07 ± 0.14	1.99 ± 0.23	1.77 ± 0.24
Weekly	2.22 ± 0.24	2.11 ± 0.26	1.11 ± 0.28	2.31 ± 0.30
Biweekly	2.46 ± 0.22	2.14 ± 0.09	2.14 ± 0.37	2.30 ± 0.19
	$LSR_{.05}$ = 0.71	$LSR_{.05}$ = 0.6	$LSR_{.05}$ = 1.38	$LSR_{.05}$ = 1.09

1. Values sharing superscripts are not significantly different at the 0.05 level using the LSR test. Comparisons are only made within a month.

between treatments at any sampling date or at peak standing crop (Table 8). The number of species recorded at each sampling date showed checks to be significantly higher ($p \leq 0.05$) than all other treatments in August and October. In September only the single application treatment was significantly different (Table 9, Figure 2). At peak community production the checks had significantly more ($p \leq 0.05$) species than all other treatments while treatment two had significantly fewer ($p \leq 0.05$) than treatments three and four (Table 9). The comparison of above ground biomass showed checks had significantly less ($p \leq 0.05$) biomass than all treatments in August, September and October (Table 10). It should also be noted that single applications tended to have higher biomass accumulations until September suggesting that the initial response period of the vegetation has much to do with the final outcome on the site.

Predictive linear regression equations (Tables A17-20) were used to estimate below ground biomass in each treatment at each time period. Comparison of these estimates using the LSR test show checks to be significantly less ($p \leq 0.05$) than weekly and biweekly application treatments in July and August. In July single application treatments had significantly less ($p \leq 0.05$) estimated under ground biomass than weekly or biweekly application treatments and significantly more ($p \leq 0.05$) than checks. In September and October, no significant differences were evident between the estimated underground biomass in any of the treatments (Table 11). The October value in the biweekly treatment may be due to increased activity of <u>Agropyron</u> during September in this treatment. These data (Table 11) show the behavior of underground plant biomass is not similar to the behavior of above ground plant biomass (Table 10). Here, the estimated mean underground plant biomass in all treatments became more similar (converged)

Table 8. Data for 1972 season at peak annual above ground standing crop. Values are derived from the four replicates of each treatment.

Treatment	Diversity (H')[1]	Evenness (J)	Biomass[2]	N[3]
Check	2.89 ± 0.13	0.58 ± 0.02	[a]820.8 ± 146.4	[a]108.4 ± 14.5
Single	2.38 ± 0.20	0.53 ± 0.04	[b]1265.8 ± 85.7	318.9 ± 16.8
Weekly	2.58 ± 0.26	0.54 ± 0.05	[b]1201.1 ± 108.1	326.0 ± 22.3
Biweekly	2.63 ± 0.23	0.55 ± 0.04	[ab]1176.3 ± 72.2	313.1 ± 36.7
	LSR = 0.96	LSR = 0.20	LSR = 372.08	LSR = 127.79

1. Values ($\overline{X}$ ± SE) sharing superscripts are not significantly different at the .05 level, using the LSR test. Comparisons are only within a month.
2. above ground living biomass in $g \cdot m^{-2}$
3. kg. nitrogen per hectare present in above ground biomass

Table 9. Number of plant species present. Values are the $\overline{X} \pm SE$ of four replicates of each treatment.

Treatment	July[1]	August	September	October	Peak
Check	21.75 ± 2.1	[a]24.50 ± 0.9	[a]20.25 ± 1.0	[a]22.25 ± 2.2	[a]32.75 ± 2.0
Single	17.25 ± 1.2	17.25 ± 1.3	[b]12.25 ± 1.3	10.75 ± 0.9	[b]22.50 ± 0.5
Weekly	20.00 ± 0.9	18.75 ± 0.9	[ab]13.25 ± 1.8	13.50 ± 2.1	27.75 ± 1.7
Biweekly	20.75 ± 1.0	18.00 ± 1.3	[ab]13.75 ± 2.2	12.75 ± 1.9	27.50 ± 1.5
	LSR = 6.50	LSR = 2.23	LLSR = 7.31	LSR = 7.8	LSR = 4.69

1. Values sharing superscripts are not significantly different at the .05 level, using the LSR test. Comparisons are only made within a month.

FIGURE 2.

Number of plant species present ($\bar{X} \pm 2$ SE)

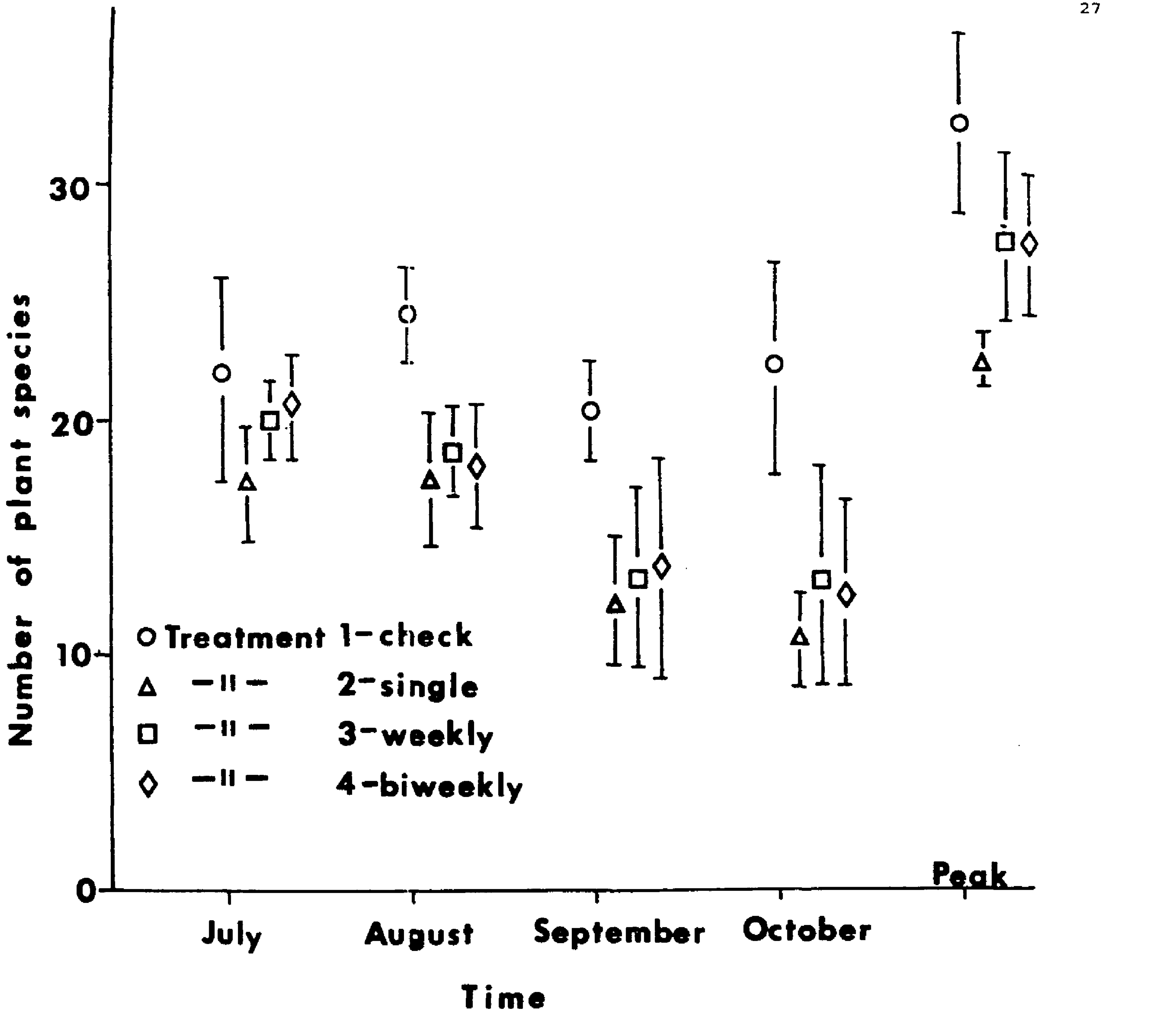

Number of plant species
30
20
10
0
Treatment 1-check
-"-
2-single
-"-
3-weekly
-"-
4-biweekly
Peak
July
August
September
October
Time

Figure 2.

Table 10. Above ground biomass ($\bar{X} \pm SE$) in $g \cdot m^{-2}$. Values were derived from four replicates of each treatment.

Treatment	July[1]	August	September	October
Check	231.9 ± 51.9	[a]418.2 ± 78.1	[a]606.9 ± 98.1	[a]523.5 ± 91.8
Single	366.7 ± 46.6	677.4 ± 56.8	1093.5 ± 78.5	776.4 ± 55.5
Weekly	302.5 ± 17.5	624.9 ± 78.0	945.8 ± 106.4	814.1 ± 40.0
Biweekly	271.1 ± 44.6	650.9 ± 88.3	973.7 ± 67.7	783.7 ± 79.2
	LSR = 142.69	LSR = 189.94	LSR = 208.74	LSR = 202.78

1. Values sharing superscripts are not significantly different at the .05 level, using the LSR test. Comparisons are only made within a month.

Table 11. Below ground biomass ($\bar{X} \pm SE$) in $g \cdot m^{-2}$. Values were derived from predicted below ground biomass in the four replicates of each treatment.

Treatment	July[1]	August	September	October
Check	$^{a}106.5 \pm 21.65$	$^{a}110.2 \pm 19.77$	214.3 ± 17.58	251.5 ± 13.35
Single	$^{a}132.1 \pm 17.09$	$^{ab}182.7 \pm 17.22$	220.0 ± 11.69	197.1 ± 32.48
Weekly	$^{b}205.3 \pm 26.78$	$^{b}240.1 \pm 21.17$	236.7 ± 35.68	196.7 ± 30.14
Biweekly	$^{c}287.7 \pm 32.60$	$^{b}275.2 \pm 37.32$	225.7 ± 25.65	318.5 ± 48.28
	LSR = 46.45	LSR = 118.4	LSR = 100.4	LSR = 143.3

1. Values sharing superscripts are not significantly different at the .05 level, using the LSR test. Comparisons are only made within a month.

across treatments from July through September, while above ground plant biomass became more separated (diverged) in treatments compared to checks from July to September.

A comparison of mean above ground biomass in each treatment at peak production showed checks to be significantly less ($p \leq 0.05$) than single and weekly application treatments (Table 8).

Since only above ground portions of plant biomass are usually harvested, only these portions were evaluated in terms of nutrient accumulation. Nutrient accumulation, expressed as kilograms of nitrogen per hectare, was significantly greater ($p \leq 0.05$) in all treatments compared to checks in August, September and October. In July, only the single and weekly application treatments differed significantly from checks (Table 12). Nitrogen accumulation at peak standing crop (Table 8) again shows checks to be significantly less ($p \leq 0.05$) than all other treatments.

Kjeldahl nitrogen was monitored at ten soil depths in each treatment. Results (Tables A32-41) show, at the 0-10 centimeter depth, nitrogen in checks to be significantly less ($p \leq 0.05$) than single application treatments only in June. The only other point in time where significant difference in nitrogen were noted was in October at the 70-80 cm. depth. These data do indicate that the amount of Kjeldahl nitrogen present at the different soil depths monitored was the same in all treatments at a single depth at one sample date.

Results for nitrate nitrogen analysis at each ten centimeters soil depth are summarized and significant differences are indicated in the tables (Tables A22-31). Graphing the mean values (Figures 3-6) for nitrate nitrogen in each treatment show that in the checks soil nitrate levels decreased over the season at all soil depths. The graph for the single

FIGURE 3.

Mean Nitrate nitrogen (ppm.) for treatment one (check) at each 10 cm. soil depth for each time interval over the season

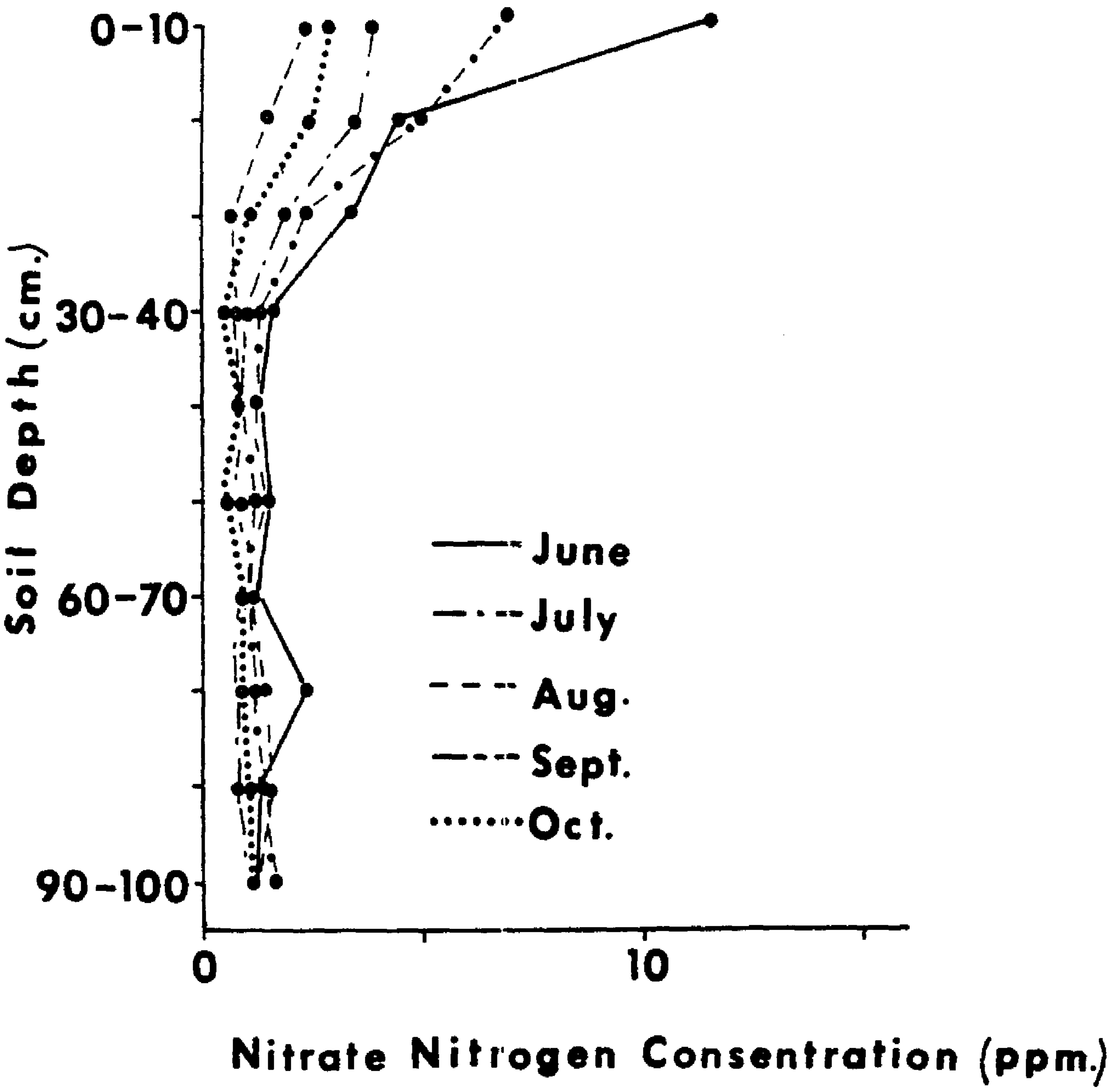

0-10
30-40
60-70
90-100
Soil Depth (cm.)
0
10
Nitrate Nitrogen Consentration (ppm.)
June
July
Aug.
Sept.
Oct.

Figure 3.

FIGURE 4.

Mean nitrate nitrogen (ppm.) for treatment two (single) at each 10 cm. soil depth for each time interval over the season

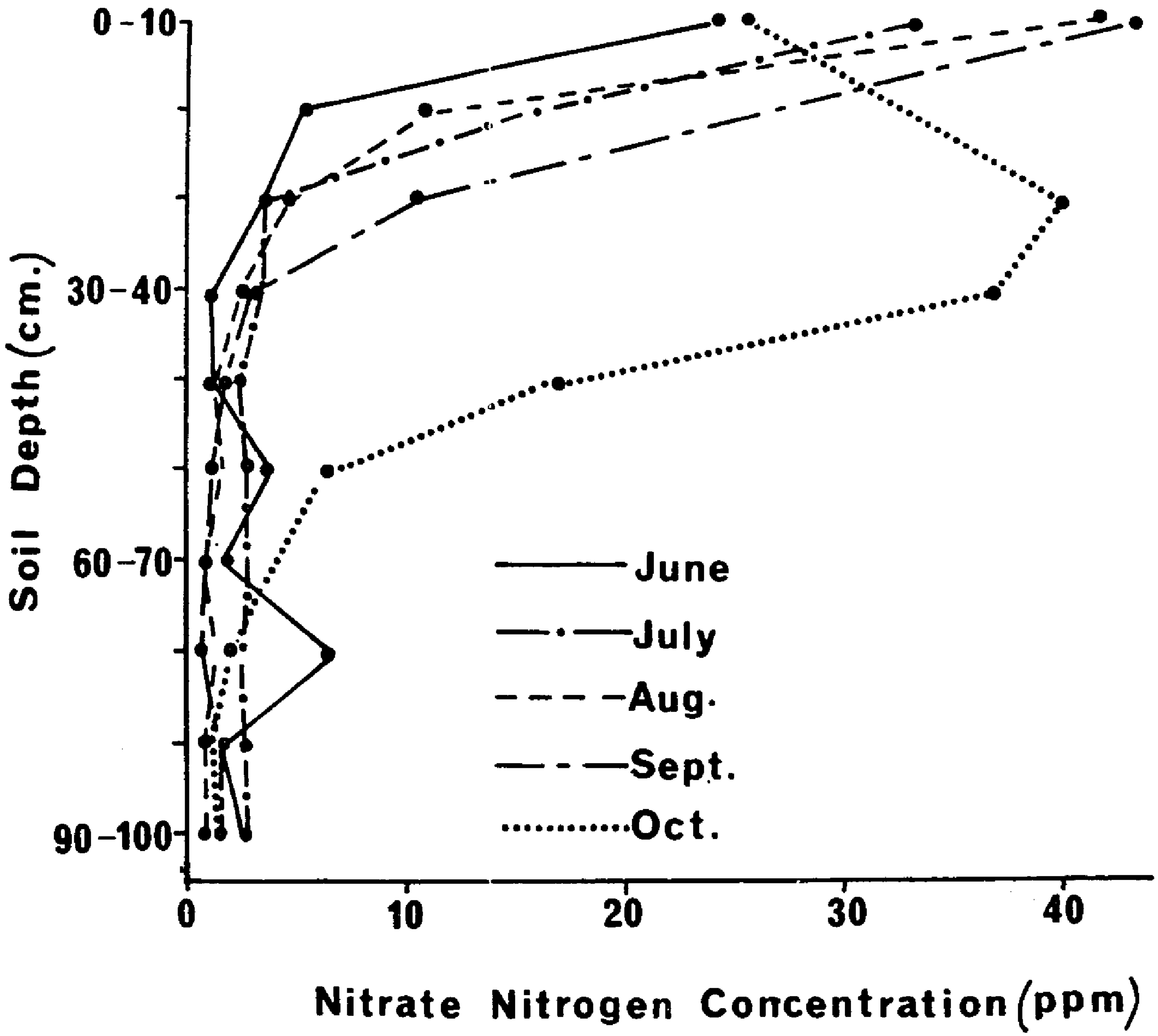

0-10
30-40
60-70
90-100
Soil Depth (cm.)
0
10
20
30
40
Nitrate Nitrogen Concentration (ppm)
June
July
Aug.
Sept.
Oct.

Figure 4.

FIGURE 5

Mean nitrate nitrogen (ppm.) for treatment three (weekly) at each 10 cm. soil depth for each time interval over the season

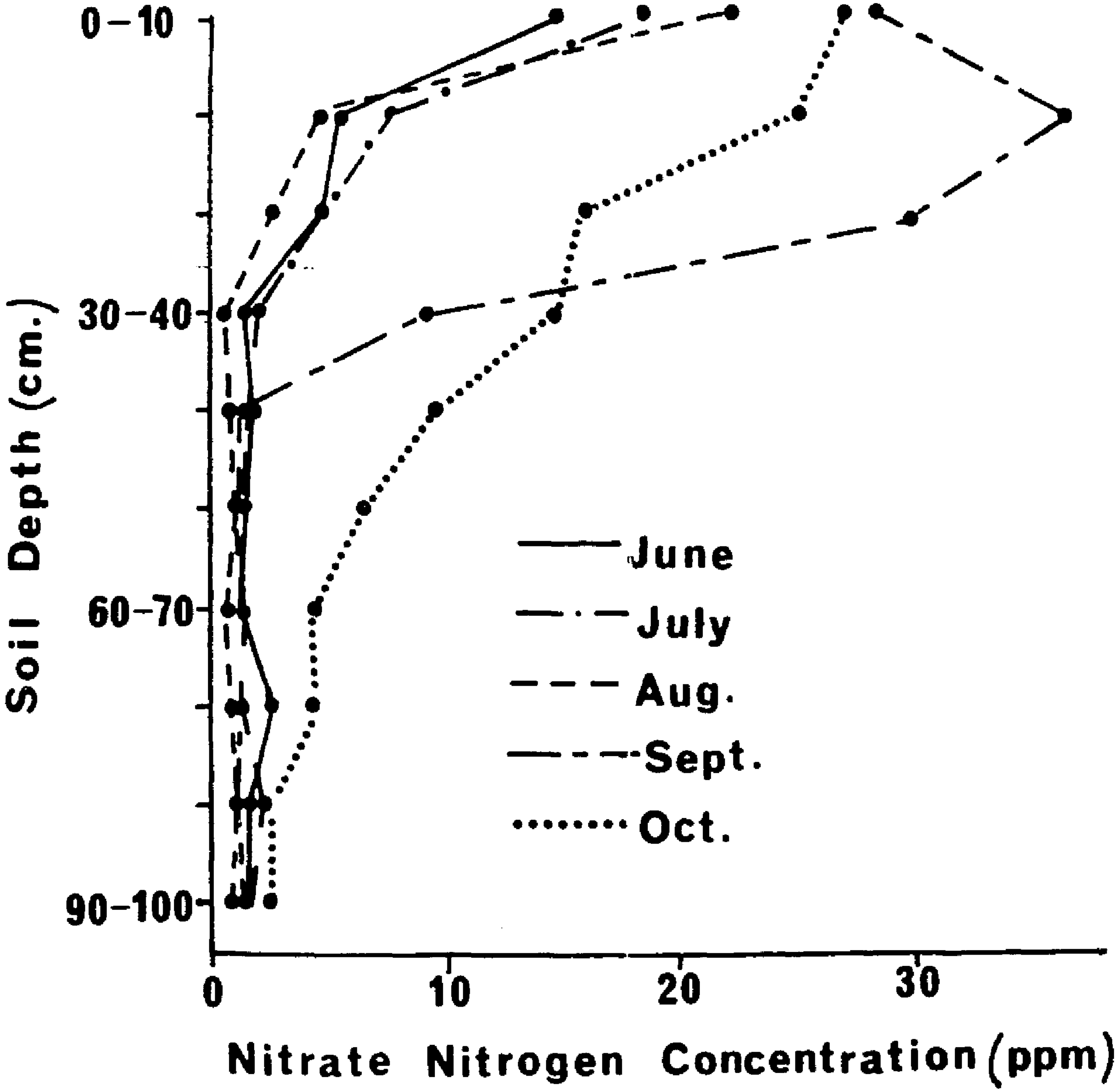
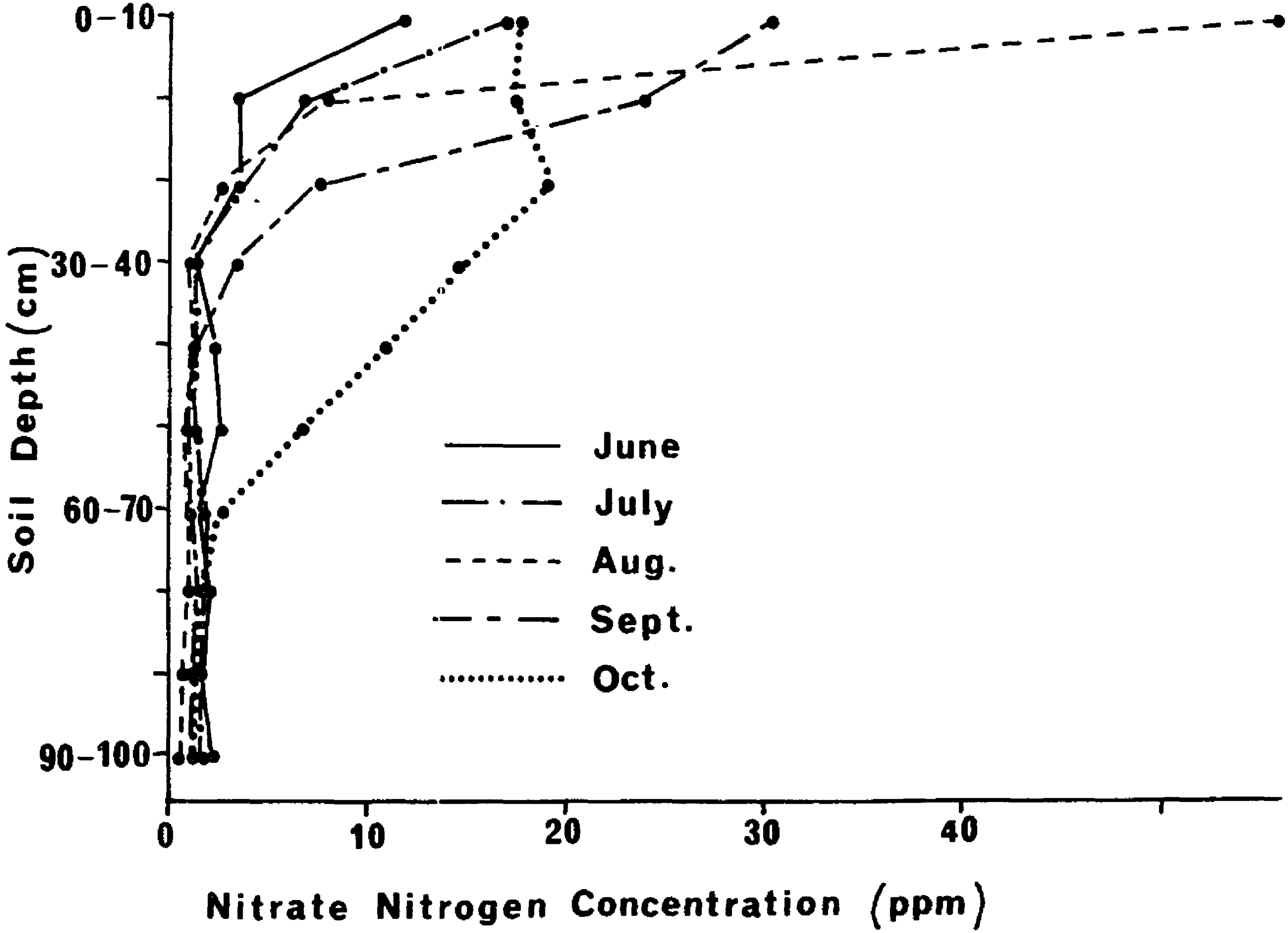

0-10
30-40
60-70
90-100
Soil Depth (cm.)
0
10
20
30
Nitrate Nitrogen Concentration (ppm)
June
July
Aug.
Sept.
Oct.

Figure 5.

FIGURE 6

Mean nitrate nitrogen (ppm.) for treatment four (biweekly) at each 10 cm. soil depth for each time interval over the season



0–10
30–40
60–70
90–100
Soil Depth (cm)
0
10
20
30
40
Nitrate Nitrogen Concentration (ppm)
June
July
Aug.
Sept.
Oct.

Figure 6.

application response (treatment two) shows nitrate levels generally increased over time in the upper thirty centimeters with substantial amounts of nitrate building up in the ten to thirty centimeter zone in October. In the weekly and biweekly application treatments the build-up of nitrate in the ten to thirty centimeter zone became apparent in September and increased more by October. It is noteworthy that weekly and biweekly application treatments appear to have two periods of nitrate build-up in the ten to thirty centimeter zone, September and October, while the single application treatment had only one, occurring in October.

DISCUSSION

The Effect of Chronic and Single Nutrient Inputs on a First Year Fallow Plant Array

Production Responses

The production responses discussed here occurred during the 1972 growing season. Climatic data (U.S. Dept. Comm., 1972) indicate this season was more moist than average with annual rainfall equal to 37.38 inches, of which over half was received during the growing season. The thirty year mean annual precipitation is 30.8 inches. Consequently, soil moisture was not considered to have any great limiting effect on the responses discussed here.

Compared to checks, fertilization increased above ground production by 54 percent in the single, 46 percent in the weekly, and 44 percent in the biweekly application treatments. The increased amount of nitrogen accumulated in vegetation (Table 12) of fertilized treatments also indicates that more nitrogen was available for plant use in these treatments. The production responses measured in this study are presented along with the results of other studies in Table 13. By comparing the production values in Table 13 one can see that in the 6-year fallow field of Hurd et al., (1971) fertilization increased production by 97 percent, while in the 17-year fallow field production was increased 71 percent. In the first-year fallow fields of Stephenson (1973a) production was not increased in the early fallow fields while production was increased 138 percent in

Table 12. Nitrogen accumulation above ground in kg. per hectare ($\overline{X} \pm SE$). Values were derived from the four replicates of each treatment.

Treatment	July[1]	August	September	October
Check	[a]48.2 ± 12.02	[a]66.7 ± 11.57	[a]75.7 ± 6.25	[a]73.4 ± 12.40
Single	[b]134.9 ± 18.51	200.9 ± 18.59	279.4 ± 15.30	180.7 ± 8.90
Weekly	[b]110.3 ± 3.33	216.2 ± 23.08	265.3 ± 28.95	192.9 ± 22.98
Biweekly	[ab]97.8 ± 18.65	230.9 ± 31.95	271.2 ± 24.95	192.9 ± 22.98
	LSR = 56.0	LSR = 57.5	LSR = 86.11	LSR = 47.7

1. Values sharing superscripts are not significantly different at the .05 level, using the LSR test. Comparisons are only made within a month.

Table 13. Field data comparison of results of this study with other studies.

Author	Nitrogen Added (kg. • ha^{-1})	Field Age	Number of species	Production (g. • m^2)	Notes
Hurd et al. (1971)	56	6	9.50	1314.0	I have assumed a 150-day growing season here.
	56	17	18.00	784.0	
	0	6	10.25	669.0	
	0	17	17.50	402.0	
Stephenson (1973a)	150	1(early)	60	841.0	early field was mainly cool season dicots (C_3)
	150	1(late)	22	2116.4	
	0	1(early)	49	855.5	late field was mainly warm season grasses (C_4)
	0	1(late)	30	886.6	all at peak annual primary productivity
Reed (tis study)	450 once	1	23	1265.8 $\pm$ 85.7	
	450 weekly	1	28	1201.1 $\pm$ 108.1	at peak net annual primary productivity
	450 biweekly	1	28	1176.3 $\pm$ 72.2	
	0	1	33	820.8 $\pm$ 146.4	

the late field that was fertilized. The lack of response in Stephenson's early fallow field was attributed to periodic drought conditions which occurred throughout the experimental period. From these data (Table 13) one can observe that, as a general rule, production is enhanced by the addition of nutrients. Here then, I have treated nitrogen as the controlling nutrient variable of production realizing that many other variables ultimately control this. Additionally, soil fertility analysis performed by the Michigan State University soil testing laboratory indicate that there were 33 pounds of available phosphorus and 182 pounds of potassium per acre in the experimental area. Neither of these nutrients was felt to be limiting for grass crops and as Black (1968) states, the supply of soil phosphorus, under practical conditions, cannot be exhausted within one growing season. It has been concluded that plants utilize two of these nitrogen forms, ammonium and nitrate ions (see Bartholomew and Clark, 1965; Black, 1968). Consequently, the addition of a large amount of available nitrogen in fertilizer, coupled with that supplied by the system itself, raised the site resources and consequently the production in the treatments.

Since nitrate was one of the plant-available forms of nitrogen (Black, 1968; Viets, 1965) supplied to plants utilized in this research, I will confine my comments in this part of the discussion to soil nitrate behavior. Although half the fertilizer nitrogen was in the ammonium form, ammonium ions are usually oxidized quickly by soil organisms (*Nitrosomonas* spp., *Nitrobacter* spp.) to nitrate (Alexander, 1961), thus making nitrate ion concentrations in the soil a good indicator of site resources with respect to nitrogen availability. Data (Figures 3-6) from this study indicates that nitrate concentration in the soil of unfertilized blocks declined from June to August, increased in September, and declined in October. The increase in nitrates observed in September may have resulted from decomposition of plants that ceased growth in August, while the decrease in nitrates observed in October was associated with increased activity of *Agropyron*, which may have used the nitrates from September in the production of underground plant parts.

Except for the large August value, the mean nitrate nitrogen concentrations in the upper thirty centimeters of soil increased through September in the single, weekly and biweekly application treatments (Figures 4-6). From September to October the amount of nitrate nitrogen in the upper ten centimeters declined in these treatments with the most pronounced effect being in the single and biweekly application treatments. Considering the upper thirty centimeters of the soil to be the active root uptake zone for nutrients for the plant array of this study, and considering the behavior of underground biomass (Table 11), it is reasonable to assume that roots of plants in single, weekly and biweekly application treatments were in contact with more available nutrient (nitrate nitrogen) for a longer period of time than plants in check treatments. The large amount of residual nitrate nitrogen in soil of the single, weekly and biweekly application treatments (Figures 4-6) also suggest that if the vegetation had been harvested in late July, additional production could have been realized in these treatments if other conditions (H_2O, temperature) for additional plant growth were met. It appears that plants in application treatments utilized the available nutrient resources (nitrate nitrogen) within the capability range of the plants present and that some other limiting resource such as light and/or space kept additional production from occurring.

The quantitative relationship between above-ground and below-ground primary production has received little attention in the ecological literature. Among the major problems in obtaining accurate estimates of root production are difficulties in sampling root biomass and the determination of consumption by soil animals.

Estimates of both below-ground production and turnover rates have been made, exemplified by the study of Monk (1966). Monk (1966) describes the relationship between above and below-ground standing crop for 16 plant species, expressing this as the root/shoot ratio at a single point in time during the growing season. However, since this relationship changes as the plant matures, a single ratio does not provide an adequate estimate of root growth during an entire growing season. I have attempted here to describe the change in root/shoot ratio over the entire growing season and, by relating this to above-ground standing crop analysis, estimate below-ground production on a unit area basis.

The below-ground biomass estimates (Table 4) include some residual perennial plant materials produced during previous growing seasons. However, the two most abundant perennials, <u>Agropyron repens</u> and <u>Sonchus asper</u>, were neither individually nor collectively major components in any treatment. Consequently, the error incurred from sampling old below-ground plant material is considered to be small. Therefore, these data (Table 11) pose some interesting questions that may be pertinent to the behavior of the vegetation of this study. These data (Table 11) indicate that with or without fertilization below-ground production, by vegetation of this study, is statistically the same in all treatments in September. This suggests that in first year fallow vegetation there is a maximum root-rhizome biomass.

These data also indicate that in the single, weekly and biweekly application treatments below-ground production reached this maximum biomass earlier in the season than in the checks. This could indicate that fertilizer application enhanced under-ground production more rapidly, resulting in increased nutrient uptake and consequently in greater aboveground production. These data also indicate that individual species responded differently to the different treatments since total aboveground production does not correlate with total below-ground production. This is certainly true for Agropyron (Tables A17-20) which was sampled separately in each treatment. Agropyron was sampled in this manner as McIntyre (1972) has demonstrated increasing nitrogen supply to Agropyron by the addition of NH_4NO_3 causes buds to produce shoots rather than rhizomes. This occurred when McIntyre grew Agropyron in a solution containing 210 ppm. N a level lower than that in the soil solution of the upper soil zones in the single application treatment (Figure 4). Also, McIntyre reports a gradient of differentiation response of buds along the rhizome as the nitrogen supply in the rhizome increases presumably as a result of increased nitrogen supply in soil solution. This situation, increased nitrogen supply in soil solution, was present in the weekly and biweekly treatments (Figures 5-6). Finally it could be that the combination of plants in the plant arrays studied caused the variation observed between treatments. Since these plants utilize about the same depth of substrate it could be that root-rhizome biomass realized in this vegetation would only occur again in early (first-year) fallow vegetation.

Number of Species

Fertilization results in a decreased number of species in first year fallow vegetation (Table 9). Comparing these data with data of other studies (Table 13) show this also occurred in other first year fallow vegetation. Again, the lack of response in Stephenson's early field was attributed to drought. This reduction in species number could be explained, in part, by the structure and life cycle (annual, biennial, perennial) of the vegetation present in the experimental plots. In this study the dominant plant species were annuals, plants that responded rapidly to nutrient addition, and one perennial grass, Agropyron. The plant species responding most rapidly to nutrient addition were able to occupy the above and below-ground space more rapidly in the treatments than in checks (Tables 10, 11). Thus, the plant array was essentially closed to additional species. An examination of Tables A1-16 indicates that rarer plant species (Oxalis stricta, Daucus carrota, Panicum dichotomiflorum, Portulaca oleracea, Physalis spp., Melilotus officinalis) were some eliminated in fertilized arrays. Two of these species, Portulaca and Oxalis, do not attain any great height and all of these were late appearing and contributed little biomass in the checks. The loss of additional species in fertilized vegetation was of longest duration in the single application (Table 9). This indicates that chronic application of nutrients, at levels used in this study, does not eliminate species to the same extent as single application. One might suggest that fertilizer itself caused the elimination of species due to toxic chemical effects. However, most of the eliminated species are common agricultural weeds that exist in row crops receiving high fertilizer application.

The relationship of number of species to production in successional and seasonal time has received some attention in recent years (McNaughton, 1968; Loucks, 1970; Hurd et al., 1971). However, no agreement concerning this relationship has been reached. In the geographic area of this study, an inverse relationship was found between number of species and production during a single growing season. The relationship of the number of species acting as an independent variable controlling production has recently received criticism (Stephenson, 1973a). He states that it is production, acting as an independent variable which determines the number of species present. Data of this study tentatively support this hypothesis (Tables 9, 10) in first year fallow vegetation. Increased nutrients in the soil of treatment blocks allowed plants in these areas to express themselves earlier in the season through increased production, thus saturating the available growing space more rapidly. This would eliminate species from occupying open ground sites later in the season. Here then, over seasonal time, increased production from fertilization operated as the independent variable that generated the number of species measured.

Nutrient Accumulation

Since in most waste water renovation programs the nutrient reclaimed in harvestable vegetation will be important, I will here discuss nutrient accumulation (nitrogen) in above-ground plant material. These data (Table 12) indicate that in this study the amount of nitrogen accumulated by above-ground plant material in all fertilized treatment blocks was the same at all sampling dates. This indicates that the amount of nutrient uptake by plant material in treatment blocks is independent of the application schedule. To examine the proportion of nitrogen reclaimed by the system in reference to that applied it is necessary to calculate the following:

$$\% \text{ reclaimed} = \frac{(\bar{X} \text{ N in tmt}) - (\bar{X} \text{ N in checks})}{\text{Tot. N added to tmt}}$$

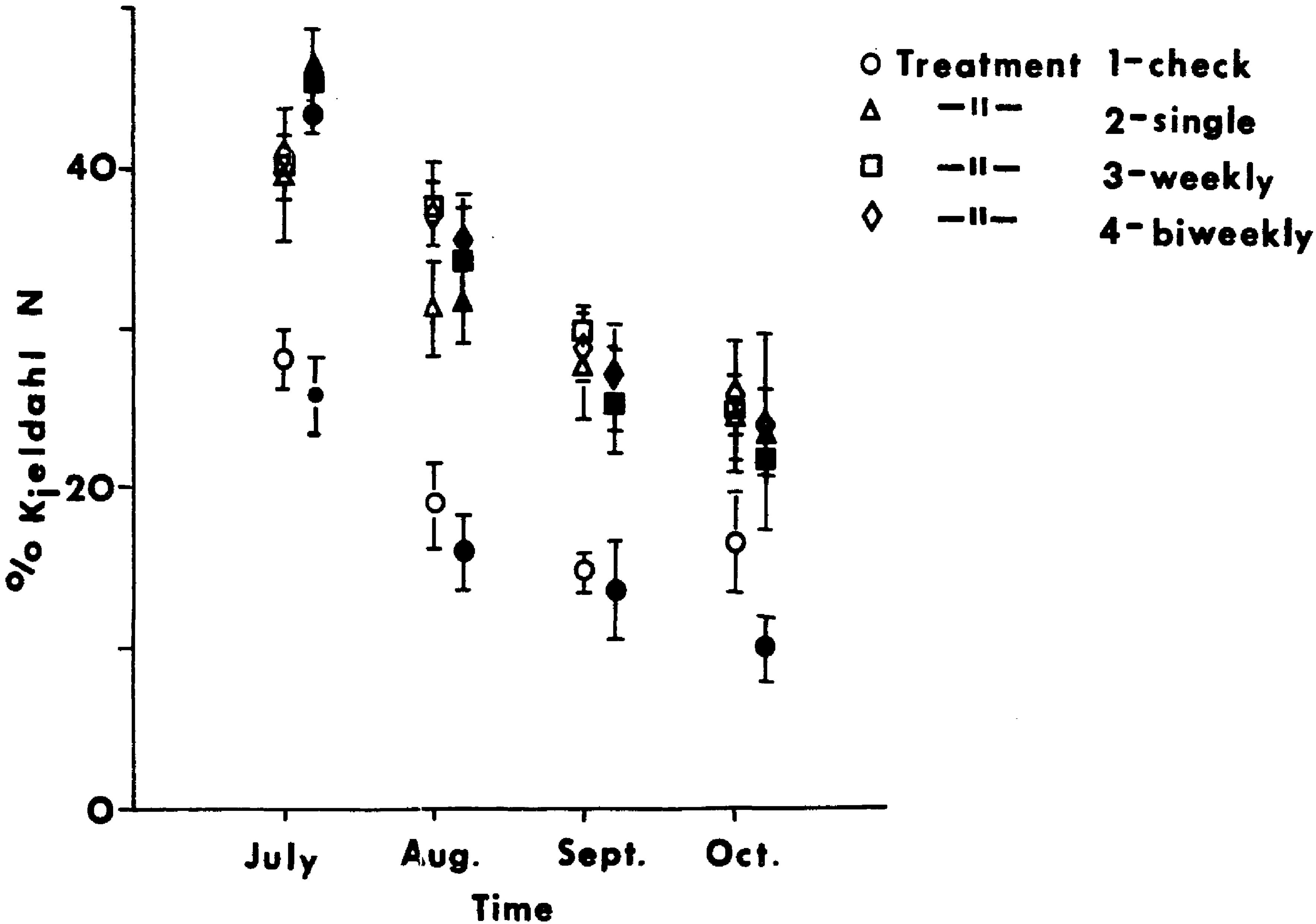
At the time of greatest nitrogen accumulation in each treatment application, September, the single applications reclaimed 45 percent, the weekly 42 percent, and the biweekly 43 percent of the amount applied. At peak vegetation biomass the percent reclaimed was 47 percent, 48 percent, and 45 percent in the single, weekly, and biweekly applications respectively. These data (Table 7) indicate that under any of the application schedules followed the greatest quantity of harvestable nutrient in the system is present in September and amounts to approximately 270 kg. N. ha^{-1}. The species of plant producing the plant material on a site will also have a great deal to do with the amount of nutrient taken into harvestable biomass. Data in this study (Table 2, Figure 7) show that C_3 plants (for a discussion of C_3 and C_4 plants see Black, 1970; Caswell et al., 1973) tend to contain higher quantities of nitrogen per gram of tissue than C_4 plants. This is in agreement with data of Wilson and Haydock (1971) working with tropical (C_4) and temperate (C_3) grasses in response to varying nitrogen levels. Expanding these results (Figure 7) to a large area, it would appear that C_3 plants as a group will take up more nutrient per unit area than C_4 plants, providing production of the two types is equal. Also, C_4 plants may be a poorer source of food for herbivores (Caswell et al., 1973) and thus make a poorer forage crop, although ruminants present a different situation than monogastric herbivores. The amount of nitrate nitrogen accumulated by vegetation is also important if the vegetation is to be considered for use as forage. The acceptable level of nitrate in forage for consumption is 0.21 percent (Adriano, personal communication). Using the technique of Baker and Smith (1969) data in this study (Table 14) indicate that for the tested plant species present, plant material from checks would all be acceptable. In the weekly and biweekly application treatments only Agropyron has an acceptable nitrate level for forage, and this occurred only in July and August.

FIGURE 7

Kjeldahl nitrogen ($\overline{X} \pm 2SE$).

Open symbols indicate C_3 species.

Closed symbols indicate C_4 species.



Treatment 1-check
—"— 2-single
—"— 3-weekly
—"— 4-biweekly
40
20
0
% Kjeldahl N
July
Aug.
Sept.
Oct.
Time

Figure 7.

Table 14. Percent nitrate nitrogen present in vegetation in each treatment over time. Values were determined from one sample of plant material.

Treatment	Species	July	August	September
	Agropyron repens	0.007	0.006	0.002
	Amaranthus retroflexus	0.096	0.006	0.003
Check	*Chenopodium album*	0.052	0.015	0.007
	Setaria spp.	0.046	0.002	0.003
	Agropyron repens	0.223	0.257	0.235
	Amaranthus retroflexus	1.09	0.829	0.597
Single	*Chenopodium album*	1.00	1.23	0.917
	Setaria spp.	0.792	0.775	0.703
	Agropyron repens	0.183	0.164	0.338
	Amaranthus retroflexus	1.09	0.748	0.517
Weekly	*Chenopodium album*	0.994	0.829	0.588
	Setaria spp.	0.733	0.557	0.500
	Agropyron repens	0.203	0.091	0.235
	Amaranthus retroflexus	1.53	0.620	0.740
Biweekly	*Chenopodium album*	0.984	0.702	0.489
	Setaria spp.	0.613	0.613	0.563

As Black (1970) states, C_4 plants are more efficient in their use of water, using less to produce a unit of biomass than C_3 plants. Consequently, the use of C_4 plants in waste water renovation needs more investigation as C_4 plants, given an available water supply similar to C_3 plants, may be capable of producing more vegetation per unit area, and thus removing more nutrient than C_3 plants. The data of Stephenson (1973a) (Table 9) from his late fallow fields indicates that C_4 plants can produce greater quantities of vegetation per unit area than C_3 plants. The C_4 plants accomplished this during a shorter growing period and thus the active period of nutrient uptake was shorter giving this system (C_4) an overall shorter period for the distribution of waste water in a waste renovation system. The data of this study (Table 14, Figure 7) suggest, however, that at the present time C_4 plants are a poor choice for use on a spray irrigation site in the renovation of waste water effluent.

A Spray Irrigation Area for Renovation of Secondary Effluent

Terrestrial plant communities have been suggested as a means of renovating waste water effluent (Sopper, 1971, Pennsylvania State). It appears that there are at least four important components of secondary effluent that will determine the effectiveness of natural plant communities in the renovation of secondary effluent. The first component is water. The movement of water through porous media (soil) has been described by Novak (1972). Too much water applied to the soil in secondary effluent could saturate the root zone of plants, terminating root respiration, and thus killing the plants occupying the site. Other plants may take their place, but these may be less desirable for the renovation of effluent. Second, the amount of phosphorus present in effluent applications should be considered.

Phosphrus is adsorbed on clay soil particles (Alexander, 1961); the type and amount of clay present in the soil column above the water table will then determine how much phosphorus the system can adsorb. The total amount of phosphorus the system can adsorb coupled with the amount of phosphorus a plant array on the site can remove in successive years will then determine the life expectancy of the site if used for waste water renovation. Third, the amount of heavy metals present in the effluent will be important. Since some plants tend to concentrate heavy metals (Antonovics, 1970) the amount accumulated by them may produce toxic levels in the vegetation and preclude its use as forage. However, it might be possible with modern technological methods to utilize plants to concentrate some heavy metals and then extract these from the plants. This certainly points toward further investigation in this area. Fourth, the amounts and forms of nitrogen in secondary effluent will have much to do with the success of a spray irrigation site. Nitrate nitrogen will be especially important in view of the fact that the anion is very mobile and tends to move through the soil column with water if not utilized by plants and/or soil microbes.

A spray irrigation system for the renovation of secondary effluent must encompass the interactions that occur between soil, plants, and animals. Here, I have attempted to deal with one on these interactions, the soil and plants associated with it, using fertilizer as the forcing function. Nitrogen from secondary effluent can be introduced into the soil system in basically four forms; organic nitrogen, ammonium ions, nitrite ions, and nitrate ions. The form of nitrogen introduced is important in that it will determine the residence time of nitrogen in the active soil zones for root absorption. Organic nitrogen is trapped in the upper soil layers and must be converted to ammonium ions through the action of soil microbes. The process of mineralization is slow (Alexander, 1961); consequently, the nitrogen will be released slowly (Bartholomew, 1965). Ammonium ions, already an available form for plant use, can be adsorbed by clay particles or through the process of aerobic bacterial nitrification oxidized to nitrate. The rate at which these reactions take place is determined at least in part by abiotic factors (water, soil atmosphere, temperature, pH) of the soil material. Also, the amount of nitrogen available for plant use from decomposition of organic matter will be a function of the carbon to nitrogen ratio in the vegetation and in the organisms decomposing the vegetation (Alexander, 1961). If the C/N ratio in plant material is high (>20:1) nitrogen from the decomposition process will be more immobilized (a nitrogen limited system) while if the C/N ratio in plant material is low (<20:1) nitrogen will be mineralized more rapidly (a carbon limited system) (see Alexander, 1961; Burges and Raw, 1967; Cromack, 1972). Also, abiotic factors of substrate temperature, moisture and oxygen status will be important in the decomposition process (Witkamp, 1966, 1971). Finally, it is the fate of nitrate ions leached from active plant root zones that may determine the effectiveness of the site for use in water renovation of secondary effluent. These leached nitrate ions can only be removed from the system, without entering ground water, through the process of denitrification in the anaerobic soil zones (Tusneem and Patrick, 1971). This process is part of the entire processing system and needs more extensive investigation in field situations if we are to understand and utilize denitrification.

The form of nitrogen that appears to be most suitable for spray irrigation of secondary effluent is a mixture of organic nitrogen in conjunction with ammonium and nitrate ions. Organic nitrogen would be favored since there is a slow release of available nitrogen from its breakdown. However, most secondary effluent contains very little organic nitrogen, suggesting that primary effluent may be more useful in spray irrigation. Also, the addition of an available carbon source to the effluent may lead to the utilization of available nitrogen by microbes and thus keep the nitrogen in the upper soil zones. This would change the C/N ratio in the substrate.

If nutrients (nitrogen and phosphorous) are made available in large amounts at the beginning of the growing season in first year fallow vegetation, the plant species present early in the growing season will utilize them rapidly thus reducing or eliminating species that may commence growth at a later date. Consequently, over time (season) there will tend to be a reduction in the number of plant species (Table 9, Treatment 2). However, if nutrients are made available in pulses through a controlled irrigation schedule the loss in number of species over time (season) may not be as great (Table 9, Treatments 3,4). Therefore, in a spray irrigation system for the application of secondary effluent, the application schedule should be arranged in such a manner to create asynchrony in the growth phases of plants in the plant array. This asynchrony (early season plants, late season plants) would then allow the active nutrient (nitrogen) accumulation period in plants of the array to be extended beyond those in synchronous monocultures.

As previously mentioned, the type of plant species supported by the site will be important especially in terms of C_3 and C_4 plants, and possibly a balanced system could be created utilizing each of these groups in conjunction with a harvesting schedule that opens the community for additional occupation by other plants.

After the production of plant material under spray irrigation with secondary effluent what does one do with the harvestable vegetation? If left on the spray site the material will decompose and may add to the already enlarged nutrient pool. If the plant material is harvested it might be used as forage, providing nitrate levels in the vegetation are not toxic to potential consumers. Also, the plant material could be used to improve poor and/or excessively well-drained soils (sand). As previously mentioned, if the C/N ratio in the vegetation is high (>20:1) decomposition favors immobilization of nitrogen, and the addition of this plant material to poorer nutrient quality soils will also raise the organic matter content of the soil. Raising the organic matter content of the soil will increase the water holding capacity of the soil and may enable the area to support more vegetation. This aspect needs further investigation. Industrial use of this plant material produced on a waste water renovation site may also be an alternative, but research is just beginning in this area. However, it is apparent that some use must be found for this vegetation as it cannot be left on the spray site.

Finally, some have suggested that spray irrigation using secondary effluent can be utilized in this region, for the renovation of waste water, throughout the year. I believe this needs further critical examination as it appears that winter application of effluent will only result in a build-up of available nutrient in the substrate which may favor species commencing growth early in the season. This would have an effect similar to single application treatments (treatment two).

The use of terrestrial plant communities for the renovation of secondary effluent requires a more detailed understanding of the behavior of the total system than we presently have. Therefore, I would suggest that waste water renovation programs be approached cautiously.

CONCLUSIONS

In conclusion I believe that this study has brought out at least the following points:

1. Within a first year fallow field vegetation, as above-ground production increased through fertilization, the number of plant species decreased (Tables 9, 10).

2. Chronic application of fertilizer at low levels without harvesting increased production to the same extent as single applications (Table 9), provided the total amount of fertilizer applied is the same. Also, the number of plant species at peak net annual above ground production tends not to be reduced to the same extent in chronic application treatments as it was in the single application treatment (Table 9).

3. Over the growing season, C_3 plants tend to accumulate more nitrogen per gram of tissue than C_4 plants (Figure 7).

4. Nitrate nitrogen levels in vegetation from check communities was at a safe level for use of the vegetation as forage. However, in the single application treatment no vegetation was safe for use as forage. In the weekly and biweekly application treatments only Agropyron in July and August had nitrate levels in the plant that would allow its safe use as forage (Table 14).

5. Under fertilization of 450 kg. $N \cdot ha^{-1}$ without water, using any of the application schedules of this study, the first year fallow plant array of this study accumulated in above ground vegetation an amount of nitrogen equal to about 45 percent of the amount of nitrogen applied.

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LITERATURE CITED

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APPENDIX

Tables A1-16. Summary of the biomass contributed to above ground production by each species at each interval in time over the season. Check communities were blocks 4, 5, 11 and 14. Single application treatments were blocks 3, 6, 9 and 16. Weekly applications were in blocks 2, 7, 12 and 13. Biweekly applications were in blocks 1, 8, 10 and 15.

Table A1. Summary of Block 1. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	117.2	220.5	226.9	158.0
Amaranthus retroflexus	6.3	15.0	62.5	26.1
Ambrosia artemisiifolia	0.4		111.6	0.15
Barbarea vulgaris	0.1			
Chenopodium album	1.1	12.83	2.6	12.5
Cirsium vulgare		0.03		1.1
Cyperus esculentus	6.8		0.5	
Daucus carrota				9.9
Digitaria sanguinalis		0.2	1.4	
Echinochloa crusgalli	0.1	0.03	9.0	22.1
Euphorbia spp.		0.03		
Lychnis alba	0.03			
Medicago sativa	0.8			
Medicago lupilina	0.4		1.4	
Melilotus officinals			0.4	0.3
Panicum capillare	5.63	26.7	28.2	52.1
Phalaris arundinacea	6.5	0.4	2.0	15.2
Poa compressa			0.4	0.25
Polygonum convulvulus	3.7	4.0	20.0	0.9
Polygonum pensylvanicum	3.2	74.5	64.1	178.8
Polygonum persicaria	0.5	0.6		6.0
Portulaca oleracea	0.1	0.1		
Setaria glauca	12.7	28.9	85.0	28.3
Setaria viridis	13.7	59.9	210.2	45.9
Solidago canadensis				0.9
Taraxacum officinale	0.23	0.23	0.7	0.66
Thlaspi arvense	0.1			
Trifolium repens	0.03	0.03	0.03	
Verbascum blattaria		0.4		
Unknown		0.1		

Table A2. Summary of Block 2. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Acalypha spp.			1.8	1.66
Agropyron repens	99.7	173.6	203.8	80.0
Amaranthus retroflexus	3.1	21.83	37.2	
Ambrosia artemisiifolia	4.5	32.8	7.2	19.0
Barbarea vulgaris		0.03		
Capsella bursa-pastoris	0.1	0.2		
Chenopodium album	11.2	82.3	13.9	118.4
Cirsium vulgare	0.03	0.13		
Cyperus esculentus				4.2
Echinochloa crusgalli	2.5	2.1	41.8	81.9
Lychnis alba	0.03			
Medicago lupilina		0.2		
Oxalis stricta		0.03		
Panicum capillare	0.3	6.3	5.2	7.9
Panicum dichotomiflorum	0.5			
Panicum spp.		2.4		
Polygonum convolvulus	1.4	0.03	0.13	
Polygonum pensylvanicum	0.2	8.8	8.8	171.1
Setaria glauca	4.0	50.8	203.1	191.3
Setaria viridis	1.6	5.33	49.7	36.8
Solanum nigrum			0.03	
Solidago canadensis	3.2	0.8		1.4
Solidago graminifolia	10.4	2.0	1.0	0.9
Sonchus asper	200.9	46.8	100.3	50.3
Taraxacum officinale	0.33	0.5	0.1	0.56
Trifolium repens	0.03	0.2		
Urtica spp.		0.4		
Verbascum blattaria	0.2			
Unknown	0.03			

Table A3. Summary of Block 3. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	198.0	298.1	338.3	317.8
Amaranthus retroflexus	1.8	0.3		0.4
Ambrosia artemisiifolia		15.6	49.0	
Aster spp.				0.03
Barbarea vulgaris	0.03	0.03		0.03
Chenopodium album	30.2	20.1	14.3	17.6
Cirsium vulgare	0.53			1.0
Digitaria sanguinalis		0.13	0.03	
Echinochloa crusgalli		0.2		0.2
Lychnis alba	1.7			
Medicago lupilina	1.8			
Panicum capillare	0.6	4.9	0.2	3.6
Polygonum convolvulus	0.2	1.4	0.6	
Polygonum pensylvanicum	7.9	104.8	443.0	318.3
Polygonum persicaria		0.1		
Rumex crispus	0.3			
Setaria glauca	20.9	5.6	2.4	2.3
Setaria viridis	5.7	13.0	58.6	1.0
Solidago canadensis	1.4	31.1		
Solidago graminifolia	12.9	13.9		27.0
Sonchus asper	1.4	0.03		
Taraxacum officinale	1.0			0.03

Table A4. Summary of Block 4. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	65.7	85.7	188.1	167.9
Amaranthus retroflexus	0.06	1.4	0.1	3.0
Ambrosia artemisiifolia	1.8	39.5	34.0	10.63
Aster spp.		0.03		3.5
Barbarea vulgaris	0.13	0.03		0.16
Capsella bursa-pastoris		0.3		
Chenopodium album	13.9	73.4	92.5	32.0
Cirsium vulgare	0.03	0.43	2.2	1.03
Digitaria sanguinalis			0.09	
Echinochloa crusgalli		2.8	0.5	
Hieracium spp.				0.03
Lychnis alba		0.1	1.5	0.6
Medicago sativa	0.2			
Medicago lupilina	0.4	0.03		
Melilotus officinals				0.03
Moss				0.06
Oxalis stricta		0.03		0.06
Panicum capillare	0.3		2.93	0.03
Panicum dichotomiflorum		0.03		
Plantago rugelli			0.4	0.03
Polygonum aviculare	0.03	0.3		0.03
Polygonum convolvulus	1.7	5.8	2.6	
Polygonum pensylvanicum	1.1	6.9	9.3	19.3
Polygonum persicaria				0.03
Setaria glauca		1.9	2.4	28.1
Setaria viridis	5.53	6.3	14.8	11.8
Solanum nigrum		0.03		
Solidago canadensis	8.7	3.0	0.2	4.6
Solidago graminifolia	7.5	1.3		1.4
Sonchus asper	1.8	0.1	20.3	10.0
Taraxacum officinale	1.03	3.43	5.1	0.96
Trifolium pratense	0.03			
Trifolium repens	0.13	0.2	1.33	0.03

Table A5. Summary of Block 5. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Acalypha spp.			3.7	0.1
Agropyron repens	43.1	24.0	63.6	87.4
Amaranthus retroflexus	7.1	11.8	66.8	25.08
Ambrosia artemisiifolia	3.1	17.7	27.2	0.9
Aster spp.		0.03		
Barbarea vulgaris	3.1	1.0	0.03	
Chenopodium album	8.4	11.7	14.9	13.2
Cirsium vulgare	1.43	1.2	0.73	1.86
Cyperus esculentus	6.5			0.6
Daucus carrota	0.83	1.13	0.1	13.73
Digitaria sanguinalis		0.2		
Echinochloa crusgalli			0.8	0.7
Glyceria spp.			0.7	
Lychnis alba	1.4			0.1
Medicago sativa	0.4	0.9		0.03
Panicum capillare	2.73	11.1	17.1	24.9
Phalaris arundinacea	14.9	16.1	8.6	0.4
Phleum pratense				1.8
Plantago lanceolata	0.2			
Plantago rugelli	0.03	0.1	0.03	0.03
Poa compressa	1.0	0.26		0.33
Polygonum aviculare				0.1
Polygonum convolvulus	4.4	2.1	9.7	
Polygonum pensylvanicum	31.1	115.4	434.8	205.8
Polygonum persicaria	3.6	7.2		1.1
Setaria glauca	16.9	78.6	166.1	284.5
Setaria viridis	10.0	4.8	17.3	16.1
Solanum nigrum			0.03	0.03
Solidago canadensis	1.3	1.8		35.2
Solidago graminifolia		2.9		
Sonchus asper	7.5	41.6	20.9	0.03
Taraxacum officinale	3.7	2.2	0.7	2.2
Thlaspi arvense	10.5	5.5		
Trifolium repens	0.09	0.43	0.03	0 [illegible]
Urtica spp.		0.8		
Unknown	0.1			

Table A6. Summary of Block 6. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	111.5	120.7	129.6	57.8
Amaranthus retroflexus	31.8	102.0	166.0	129.0
Ambrosia artemisiifolia		1.5		
Aster spp.		0.03		
Barbarea vulgaris	1.3	0.9		
Capsella bursa-pastoris		0.1		
Chenopodium album	14.6	58.7	53.4	43.9
Cirsium vulgare	1.6	1.3	0.8	0.25
Digitaria sanguinalis		0.5		
Echinochloa crusgalli		0.4	8.1	0.4
Medicago lupilina		0.1		
Panicum capillare	0.5	1.2		2.1
Polygonum convolvulus			3.7	
Polygonum pensylvanicum	121.4	374.4	851.3	667.4
Polygonum persicaria	2.8	0.6		
Setaria glauca	20.9	38.6	6.8	30.9
Setaria viridis	2.4	15.93	26.4	
Solidago canadensis	41.0	0.2	3.1	
Solidago graminifolia	0.9	1.0		
Sonchus asper	4.5	3.5		
Taraxacum officinale	2.4	0.63	0.03	0.03

Table A7. Summary of Block 7. Biomass above ground contributed by each species at each sample period (g · m^{-2}).

Species	July	August	September	October
Agropyron repens	86.7	163.3	106.8	164.4
Amaranthus retroflexus	30.8	209.7	365.3	252.4
Ambrosia artemisiifolia	1.1	0.4	5.3	1.9
Barbarea vulgaris	0.1			
Capsella bursa-pastoris		0.2	0.1	
Chenopodium album	60.1	107.9	273.7	260.2
Cirsium vulgare	0.7		0.03	0.63
Echinochloa crusgalli		2.7		0.03
Lychnis alba		0.1		
Medicago lupinlina	0.2			
Oxalis stricta		0.03	0.03	0.06
Panicum capillare	0.03	0.2		5.0
Polygonum convolvulus		4.1	11.8	0.4
Polygonum pensylvanicum	28.9	14.7	164.8	138.8
Polygonum persicaria	0.03			2.7
Setaria glauca	32.2	48.4	35.3	57.9
Setaria viridis	12.7	12.2	52.0	6.15
Solanum nigrum	0.2			0.83
Solidago canadensis	0.8	0.5	8.4	9.3
Solidago graminifolia	9.8	11.7		19.2
Sonchus asper			12.7	
Taraxacum officinale	0.13	0.6	0.63	0.83
Trifolium pratense	0.03			
Trifolium repens	0.09	0.03		0.03
Unknown		0.2		

Table A8. Summary of Block 8. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	80.7	40.3	53.6	62.6
Amaranthus retroflexus	8.6	162.3	115.1	196.6
Ambrosia artemisiifolia	0.1	7.1		
Barbarea vulgaris	0.13			
Capsella bursa-pastoris	0.03	0.2		
Chenopodium album	59.2	333.6	693.4	382.6
Cirsium vulgare	0.23			0.1
Echinochloa crusgalli				4.1
Lepidium campestre		0.2		
Lychnis alba	1.0	0.2		
Medicago lupilina		0.1		
Panicum capillare	0.13		0.03	
Plantago rugelli			0.1	
Polygonum convolvulus	10.0	2.5		
Polygonum pensylvanicum	21.9	43.2	30.2	160.3
Setaria glauca	8.7	38.1	9.0	58.2
Setaria viridis	2.3	14.6	1.5	5.3
Solanum nigrum		0.1		
Solidago canadensis	1 .5	0.1		0.75
Solidago graminifolia	0.9			
Sonchus asper	7.1	0.03		
Taraxacum officinale	0.8	0.1	0.13	0.06
Trifolium pratense		0.03		
Unknown	0.1			

Table A9. Summary of Block 9. Biomass above ground contributed by each species at each sample period (g · m^{-2}).

Species	July	August	September	October
Agropyron repens	87.9	84.3	115.4	69.1
Amaranthus retroflexus	54.2	165.0	301.9	162.4
Ambrosia artemisiifolia	1.5	10.8	16.1	
Capsella bursa-pastoris	0.03			
Chenopodium album	27.8	33.6	36.1	28.4
Cirsium vulgare	2.0	0.9	0.03	
Echinochloa crusgalli	1.9	0.7	9.1	8.4
Lychnis alba		1.8	0.03	
Medicago lupilina			0.1	
Panicum capillare	2.4	3.9	12.1	4.93
Plantago rugelli	0.03			
Poa compressa	0.1			
Polygonum convolvulus	2.2	1.4	0.8	
Polygonum pensylvanicum	89.8	322.2	502.1	237.8
Polygonum persicaria	2.3	31.0		12.0
Rumex crispus	1.2			
Setaria glauca	59.2	86.0	172.4	154.6
Setaria viridis	19.8	12.7	1 .4	2.23
Solidago graminifolia		0.3		
Sonchus asper	115.3		8.1	
Taraxacum officinale	4.0	0.53		0.06
Thlaspi arvense	27.9	4.9		
Trifolium repens		0.03		

Table A10. Summary of Block 10. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	151.6	120.1	233.2	108.8
Amaranthus alba		0.7	3.3	
Amaranthus retroflexus	8.1	7.5	144.2	126.2
Ambrosia artemisiifolia	1.7	2.3	0.4	1.2
Barbarea vulgaris	1.93			
Capsella bursa-pastoris	0.8			
Chenopodium album	58.6	197.3	203.5	194.7
Cirsium vulgare	0.5	0.06	0.03	
Echinochloa crusgalli				10.0
Erigeron annuus	0.03			
Lychnis alba	0.1		0.1	
Medicago lupilina	0.1	0.1		
Oxalis stricta		0.03		
Panicum capillare	6.4	11.8	33.1	13.4
Panicum dichotomiflorum				0.2
Plantago rugelli		0.03		
Poa compressa	0.2			
Polygonum convolvulus	0.5	0.6	1.1	
Polygonum pensylvanicum	73.9	222.7	270.0	279.6
Polygonum persicaria	3.2	14.8		0.7
Rumex crispus	1.5			
Setaria glauca	5.1	45.4	105.6	20.4
Setaria viridis	0.2	4.1	9.33	6.5
Solanum nigrum		1.1	3.7	
Solidago canadensis	8.0	2.2	1.4	
Solidago graminifolia		7.2	27.03	28.0
Stellaria media	0.03			
Taraxacum officinale	0.53	2.03	0.13	0.28
Thlaspi arvense		0.2		
Trifolium repens	0.06	0.06	0.03	

Table A11. Summary of Block 11. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	141.0	119.7	208.9	173.0
Amaranthus retroflexus	35.0	170.2	30.0	335.0
Ambrosia artemisiifolia	0.03	6.7	6.5	2.4
Aster spp.		0.03		
Barbarea vulgaris	1.9	7.4	2.43	
Capsella bursa-pastoris		0.03		
Chenopodium album	62.0	221.8	183.8	49.7
Cirsium vulgare	1.63	1.5	0.93	0.3
Echinochloa crusgalli			4.9	3.6
Lychnis alba	2.1		1.0	0.55
Medicago lupinlina	0.1	0.06	0.1	
Oxalis stricta		0.09	0.23	0.03
Panicum capillare	0.43	0.7	2.93	3.3
Plantago rugelli		0.03		
Poa compressa	0.03			
Polygonum convolvulus	4.4	1.6	3.2	1.0
Polygonum pensylvanicum	23.6	16.6	70.4	2.6
Setaria glauca	2.8	5.0	7.4	21.2
Setaria viridis	1.0	1.8	0.7	6.9
Solanum nigrum			0.03	
Solidago canadensis	7.0	32.4	28.7	
Solidago graminifolia		6.6		
Sonchus asper	15.1	1.6	31.3	15.0
Taraxacum officinale	0.43	0.76	3.3	0.46
Trifolium pratense		0.06	0.03	
Trifolium repens	0.3	0.1	0.2	0.06
Verbascum blattaria			0.03	

Table A12. Summary of Block 12. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	152.1	135.5	385.6	235.8
Amaranthus retroflexus	6.0	24.0	30.3	9.1
Ambrosia artemisiifolia	2.7	16.33	9.7	33.0
Barbarea vulgaris	0.6			
Capsella bursa-pastoris		0.2		
Chenopodium album	80.4	479.7	465.3	437.2
Cirsium vulgare	0.43	0.3	0.03	
Echinochloa crusgalli			0.6	
Euphorbia spp.		0.03		
Lychnis alba	2.1	0.1		
Medicago sativa	0.13			
Medicago lupilina	0.1			
Melilotus officinals		0.03		
Panicum capillare	0.3	0.7		
Plantago lanceolata			0.03	
Polygonum convolvulus	1.7	0.7		
Polygonum pensylvanicum	0.3	8.23	3.2	21.0
Polygonum persicaria	1.0	0.7		
Setaria glauca	1.9	2.6		
Setaria viridis	0.03	2.5	4.4	2.9
Solidago canadensis		7.8		
Solidago graminifolia				2.5
Sonchus asper	34.7			
Taraxacum officinale	0.1	0.7		
Trifolium repens	0.16			

Table A13. Summary of Block 13. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	55.5	31.0	46.2	32.2
Amaranthus alba		3.3		
Amaranthus retroflexus	101.0	415.6	597.0	209.8
Ambrosia artemisiifolia		4.8	0.2	4.5
Barbarea vulgaris	0.5			
Capsella bursa-pastoris	0.03			
Chenopodium album	3.9	15.5	89.5	58.8
Cirsium vulgare		0.43	0.5	
Daucus carrota		0.1		
Echinochloa crusgalli	0.8		8.6	
Juncus spp.		0.1		
Malva spp.	0.03			
Medicago sativa		0.3		
Panicum capillare	2.2	1.5	9.5	15.4
Phalaris arundinacea		18.2		1.2
Phleum pratense			12.2	
Poa compressa	0.3	0.33		0.03
Polygonum convolvulus	0.4		1.43	3.4
Polygonum pensylvanicum	56.5	133.8	116.1	297.6
Polygonum persicaria	0.2			0.6
Rumex crispus	1.1			
Setaria glauca	44.4	123.9	261.1	152.4
Setaria viridis	7.7	55.6	26.8	9.2
Solidago canadensis	32.0		1.1	
Solidago graminifolia				43.5
Sonchus asper	4.4		2.6	
Stellaria media	0.1			
Taraxacum officinale	0.36	0.06	0.06	0.06
Thlaspi arvense	4.7	0.3		
Trifolium pratense		0.1		
Trifolium repens	0.06			
Unknown	0.2	0.03		

Table A14. Summary of Block 14. Biomass above ground contributed by each species at each sample period (g · m^{-2}).

Species	July	August	September	October
Agropyron repens	54.7	97.5	97.9	179.9
Amaranthus retroflexus	13.4	33.7	36.1	12.7
Ambrosia artemisiifolia	1.93	7.2	25.4	1.9
Aster spp.				0.1
Barbarea vulgaris	0.9			0.03
Capsella bursa-pastoris	0.1	0.9		
Chenopodium album	40.3	134.8	101.8	48.7
Cirsium vulgare	0.6	2.83	2.23	2.2
Daucus carrota			0.03	
Digitaria sanguinalis		0.2		
Echinochloa crusgalli	1.7	1.0		2.2
Lychnis alba	0.53	3.13	12.9	2.5
Medicago sativa	1.0	0.7		
Medicago lupilina	0.2		0.03	0.03
Melilotus officinals			0.73	
Oxalis stricta		0.03	0.03	
Panicum capillare	1.4	4.5	1.2	1.6
Panicum dichotomiflorum				0.8
Physalis spp.				1.5
Plantago rugelli		0.1		
Polygonum convolvulus	0.7	8.9	5.2	
Polygonum pensylvanicum	58.5	84.0	129.4	87.2
Polygonum persicaria		0.4		
Portulaca oleracea	0.1			
Setaria glauca	16.4	14.1	52.1	33.5
Setaria viridis	31.3	49.8	71.5	56.3
Solanum nigrum		0.3		
Solidago canadensis	4.7	5.0	10.7	7.0
Solidago graminifolia		28.5	24.7	23.6
Sonchus asper	4.4	4.7	31.1	0.3
Taraxacum officinale	2.0	1.83	2.53	3.13
Trifolium pratense	0.2			0.9
Trifolium repens	0.23	0.2	0.26	
Unknown	0.03			

Table A15. Summary of Block 15. Biomass above ground contributed by each species at each sample period (g · m^{-2}).

Species	July	August	September	October
Agropyron repens	103.4	83.1	112.3	210.3
Amaranthus retroflexus	41.7	489.6	542.6	404.8
Ambrosia artemisiifolia	0.3	1.0		
Barbarea vulgaris	0.03			
Berteroa incarna	0.1			
Chenopodium album	88.3	164.1	190.4	200.9
Cirsium vulgare	0.3			0.3
Echinochloa crusgalli	30.1	4.6	16.6	5.8
Lychnis alba	11.7	0.03		0.2
Medicago lupilina			0.3	
Oxalis stricta	0.1			
Panicum capillare	0.63	0.63	1.2	
Poa compressa		0.5		
Polygonum convolvulus	7.0			
Polygonum pensylvanicum	16.2	69.7	245.7	82.0
Rumex crispus	0.2			
Setaria glauca	7.8	7.8	10.7	2.1
Setaria viridis	16.0	33.9	9.0	8.1
Solidago canadensis	24.8	2.63		
Solidago graminifolia		0.4	0.6	
Sonchus asper	16.6	18.3	0.1	
Taraxacum officinale	1.0			0.33
Thlaspi arvense	1.7			
Trifolium pratense	0.2			
Trifolium repens	0.03			
Urtica spp.		0.1		

Table A16. Summary of Block 16. Biomass above ground contributed by each species at each sample period ($g \cdot m^{-2}$).

Species	July	August	September	October
Agropyron repens	23.5	19.4	31.2	101.1
Amaranthus retroflexus	49.3	212.0	203.6	30.5
Ambrosia artemisiifolia	3.3	4.9	21.5	23.6
Aster spp.				0.15
Barbarea vulgaris	0.2			
Chenopodium album	136.8	389.0	343.6	492.7
Cirsium vulgare	0.2	0.03		
Echinochloa crusgalli	6.1		5.8	
Lychnis alba	0.4	0.2		
Medicago sativa	0.8			
Medicago lupilina	0.1		0.03	
Polygonum convolvulus	2.8	1.2	1.9	1.1
Polygonum pensylvanicum	12.6	68.6	261.9	54.9
Setaria glauca	8.7	5.9	30.7	68.5
Setaria viridis	0.5	6.8	53.9	7.2
Solanum nigrum		4.1		
Solidago canadensis	3.4	0.43	1.1	
Solidago graminifolia	3.0		2.8	
Sonchus asper	71.2	5.2	67.3	
Taraxacum officinale	0.5	0.2		0.73
Trifolium pratense		0.03		
Trifolium repens	0.03			

Table A17. Regression equations for July for underground biomass.

Species				
Agropyron repens (1)[1]	[2] $Y = 0.25 + 0.977X_1$ [3]	(r=0.99)	n=8	$p \leq 0.01$
(2)	$Y = 0.42 + 0.664X_1$	(r=0.93)	n=8	$p \leq 0.01$
(3)	$Y = 0.24 + 1.\ 6\ X_1$	(r=0.91)	n=8	$p \leq 0.01$
(4)	$Y = -0.33 + 2.21\ X_1$	(r=0.99)	n=8	$p \leq 0.01$
Amaranthus retroflexus	$Y = 0.09 + 0.18\ X_1$	(r=0.95)	n=12	$p \leq 0.01$
Ambrosia artemisiifolia	$Y = 0.08 + 0.14\ X_1$	(r=0.92)	n=11	$p \leq 0.01$
Chenopodium album	$Y = -0.01 + 0.1\ X_1$	(r=0.96)	n=12	$p \leq 0.01$
Polygonum pensylvanicum	$Y = 0.03 + 0.19\ X_1$	(r=0.98)	n=12	$p \leq 0.01$
Setaria glauca	$Y = -0.02 + 0.27\ X_1$	(r=0.97)	n=12	$p \leq 0.01$
Sonchus asper	$Y = 0.23 + 0.32\ X_1$	(r=0.93)	n=11	$p \leq 0.01$

1. Number in parentheses designates treatment number.
2. Y = predicted root weight.
3. X_1 = measured shoot weight.

Table A18. Regression equations for August for underground biomass.

Species		Equation	r	n	p
Agropyron repens	(1)[1]	[2] $Y = 0.28 + 0.449X_1$ [3]	(r=0.94)	n=8	$p \leq 0.01$
	(2)	$Y = -0.01 + 0.62\ X_1$	(r=0.89)	n=8	$p \leq 0.01$
	(3)	$Y = 0.25 + 1.09\ X_1$	(r=0.99)	n=8	$p \leq 0.01$
	(4)	$Y = 1.51 + 1.48\ X_1$	(r=0.96)	n=8	$p \leq 0.01$
Amaranthus retroflexus		$Y = 0.15 + 0.17\ X_1$	(r=0.98)	n=12	$p \leq 0.01$
Ambrosia artemisiifolia		$Y = -0.02 + 0.21\ X_1$	(r=0.96)	n=12	$p \leq 0.01$
Chenopodium album		$Y = 0.01 + 0.229X_1$	(r=0.98)	n=12	$p \leq 0.01$
Polygonum pensylvanicum		$Y = -0.03 + 0.15\ X_1$	(r=0.99)	n=12	$p \leq 0.01$
Setaria glauca		$Y = 0.06 + 0.14\ X_1$	(r=0.99)	n=12	$p \leq 0.01$
Sonchus asper		$Y = 0.66 + 0.36\ X_1$	(r=0.82)	n=12	$p \leq 0.05$
Thlaspi arvense		$Y = -0.01 + 0.06\ X_1$	(r=0.97)	n=12	$p \leq 0.01$

1. Number in parentheses designates treatment number.
2. Y = predicted root weight.
3. X_1 = measured shoot weight.

Table A19. Regression equations for September for underground biomass.

Species					
Agropyron repens (1)[1]	[2]$Y = -0.22 + 0.72\ X_1$[3]	($r=0.99$)	$n=4$	$p \leq 0.05$
(2)	$Y = -0.48 + 0.45\ X_1$	($r=0.99$)	$n=4$	$p \leq 0.05$
(3)	$Y = -0.62 + 0.52\ X_1$	($r=0.97$)	$n=4$	$p \leq 0.05$
(4)	$Y = -0.02 + 0.74\ X_1$	($r=0.99$)	$n=4$	$p \leq 0.05$
Amaranthus retroflexus	$Y = 0.04 + 0.103X_1$	($r=0.97$)	$n=24$	$p \leq 0.01$
Ambrosia artemisiifolia	$Y = 0.62 + 0.10\ X_1$	($r=0.99$)	$n=19$	$p \leq 0.01$
Chenopodium album	$Y = -0.02 + 0.15\ X_1$	($r=0.91$)	$n=24$	$p \leq 0.01$
Polygonum pensylvanicum	$Y = 0.22 + 0.13\ X_1$	($r=0.97$)	$n=24$	$p \leq 0.01$
Setaria glauca	$Y = 0.05 + 0.13\ X_1$	($r=0.90$)	$n=24$	$p \leq 0.01$
Sonchus asper	used equation for August 1972			

1. Number in parentheses designates treatment number.
2. Y = predicted root weight.
3. X_1 = measured shoot weight.

Table A20. Regression equations for October for underground biomass.

Species					
Agropyron repens (1)[1]	[2]$Y = 2.82 + 1.25\ X_1$[3]	$(r=0.92)$	$n=4$	$p\leq0.10$
(2)	$Y = -0.96 + 0.91\ X_1$	$(r=0.99)$	$n=4$	$p\leq0.05$
(3)	$Y = 1.49 + 0.78\ X_1$	$(r=0.99)$	$n=4$	$p\leq0.05$
(4)	$Y = -1.49 + 0.68\ X_1$	$(r=0.99)$	$n=4$	$p\leq0.05$

Equations for September 1972 were used for all other species.

1. Number in parentheses designates treatment number.
2. Y = predicted root weight.
3. X_1 = measured shoot weight.

Table A21. Ecological analogs for prediction of underground biomass.

Prediction equation for:	Also used for:
Agropyron repens	Glyceria spp. Phalaris arundinacea
Amaranthus retroflexus	
Ambrosia artemisiifolia	
Chenopodium album	
Polygonum pensylvanicum	Polygonum aviculare P. convolvulus P. persicaria
Setaria glauca	Cyperus esculentus Digitaria sanguinalis Echinochloa crusgalli Panicum capillare P. dichotomiflorum P. virgatum Setaria viridis
Sonchus asper	Cirsium arvense Daucus carrota Plantago lanceolata P. rugelli Rumex crispus Taraxacum officinale
Thlaspi arvense	Barbarea vulgaris Berteroa incarna Capsella bursa-pastoris

Tables A22-A31. Nitrate nitrogen ($\overline{X} \pm SE$) in parts per million for soil increments of 10 cm. from 0-100 cm. depth. Values sharing superscripts are not significantly different at the 0.05 level. To obtain ppm. in soil solution, multiply each value by ten. LSR values from Tukey's test and are compared only within a time period and depth.

Table A22. Depth 0-10 cm.

Tmt	June	July	August	September	October
1	11.43 ± 1.76	[a]6.81 ± 1.17	2.26 ± 0.37	3.85 ± 1.03	[a]2.79 ± 0.46
2	24.16 ± 2.69	[b]32.90 ± 7.28	41.11 ± 19.02	43.32 ± 32.11	[b]25.99 ± 9.27
3	14.77 ± 2.00	[ab]18.33 ± 3.02	21.73 ± 8.30	28.35 ± 8.31	[b]26.71 ± 11.16
4	12.15 ± 3.62	[ab]17.85 ± 3.13	55.31 ± 10.01	30.11 ± 8.03	[ab]17.84 ± 3.64
	LSR = 13.43	LSR = 19.53	LSR = 61.21	LSR = 65.79	LSR = 18.99

Table A23. Depth 10-20 cm.

Tmt	June	July	August	September	October
1	4.21 + 1.08	4.91 ± 1.28	1.55 ± 0.36	[a]3.47 ± 1.01	[a]2.44 ± 0.49
2	5.69 ± 1.86	15.54 ± 3.56	10.74 ± 3.57	[ab]26.07 ± 8.67	[b]33.96 ± 14.66
3	5.03 ± 1.48	7.50 ± 1.42	4.93 ± 1.10	[b]36.01 ± 10.24	[ab]24.90 ± 9.23
4	3.84 ± 1.00	6.95 ± 1.83	7.80 ± 1.28	[ab]23.70 ± 1.66	[ab]17.72 ± 4.85
	LSR = 7.76	LSR = 11.85	LSR = 9.88	LSR = 30.93	LSR = 31.39

Table A24. Depth 20-30 cm.

Tmt	June	July	August	September	October
1	3.29 ± 0.74	2.11 ± 0.62	0.79 ± 0.08	[a]1.88 ± 0.55	[a]1.11 ± 0.17
2	3.76 ± 1.05	3.79 ± 0.56	4.15 ± 2.07	[ab]10.23 ± 1.59	[b]40.00 ± 16.00
3	4.39 ± 0.77	4.34 ± 2.29	2.19 ± 0.64	[b]29.66 ± 9.55	[ab]15.71 ± 7.51
4	3.96 ± 1.76	3.95 ± 0.40	2.72 ± 0.49	[ab]7.44 ± 2.23	[ab]18.98 ± 4.77
	LSR = 5.10	LSR = 5.58	LSR = 4.36	LSR = 27.12	LSR = 37.63

Table A24. Depth 20-30 cm.

Tmt	June	July	August	September	October
1	3.29 + 0.74	2.11 ± 0.62	0.79 ± 0.08	[a]1.88 ± 0.55	[a]1.11 ± 0.17
2	3.76 ± 1.05	3.79 ± 0.56	4.15 ± 2.07	[ab]10.23 ± 1.59	[b]40.00 ± 16.00
3	4.39 ± 0.77	4.34 ± 2.29	2.19 ± 0.64	[b]29.66 ± 9.55	[ab]15.71 ± 7.51
4	3.96 ± 1.76	3.95 ± 0.40	2.72 ± 0.49	[ab]7.44 ± 2.23	[ab]18.98 ± 4.77
	LSR = 5.10	LSR = 5.58	LSR = 4.36	LSR = 27.12	LSR = 37.63

Table A25. Depth 30-40 cm.

Tmt	June	July	August	September	October
1	1.49 ± 0.59	1.16 ± 0.13	0.78 ± 0.10	0.81 ± 0.30	[a]0.68 ± 0.10
2	1.22 ± 0.34	3.28 ± 1.48	2.39 ± 1.02	2.64 ± 0.95	[b]36.62 ± 15.90
3	1.26 ± 0.33	1.62 ± 0.22	0.78 ± 0.24	9.25 ± 3.35	[ab]14.34 ± 7.31
4	1.72 ± 0.65	1.45 ± 0.18	1.04 ± 0.08	3.14 ± 1.19	[ab]14.11 ± 4.61
	LSR = 1.82	LSR = 3.79	LSR = 2.18	LSR = 9.28	LSR = 32.56

Table A26. Depth 40-50 cm.

Tmt	June	July	August	September	October
1	1.25 ± 0.26	1.09 ± 0.15	0.70 ± 0.04	0.78 ± 0.24	[a]0.78 ± 0.07
2	1.48 ± 0.51	2.07 ± 0.53	1.45 ± 0.47	1.53 ± 0.59	[b]16.72 ± 4.63
3	1.78 ± 0.35	1.44 ± 0.36	1.01 ± 0.51	1.40 ± 0.27	[ab]9.38 ± 4.61
4	2.35 ± 1.32	1.41 ± 0.16	1.42 ± 0.48	1.41 ± 0.34	[ab]10.72 ± 3.66
	LSR = 3.29	LSR = 1.48	LSR = 2.05	LSR = 2.02	LSR = 12.95

Table A27. Depth 50-60 cm.

Tmt	June	July	August	September	October
1	1.42 ± 0.40	1.13 ± 0.12	0.80 ± 0.19	1.29 ± 0.18	0.62 ± 0.03
2	3.91 ± 1.55	2.68 ± 0.80	1.66 ± 0.31	1.22 ± 0.33	6.12 ± 2.64
3	1.43 ± 0.16	1.18 ± 0.06	1.16 ± 0.45	1.46 ± 0.24	6.12 ± 2.74
4	2.71 ± 1.01	1.46 ± 0.23	0.96 ± 0.06	1.16 ± 0.17	6.65 ± 2.49
	LSR = 4.10	LSR = 1.99	LSR = 1.04	LSR = 0.58	LSR = 9.85

Table A28. Depth 60-70 cm.

Tmt	June	July	August	September	October
1	1.25 ± 0.15	1.27 ± 0.26	1.20 ± 0.19	0.82 ± 0.11	0.94 ± 0.15
2	1.59 ± 0.51	2.66 ± 0.53	0.98 ± 0.11	1.02 ± 0.16	3.98 ± 1.82
3	1.23 ± 0.23	1.38 ± 0.23	0.92 ± 0.07	1.28 ± 0.27	4.11 ± 1.42
4	1.77 ± 0.43	1.93 ± 0.28	1.06 ± 0.09	1.13 ± 0.19	2.74 ± 0.51
	LSR = 1.22	LSR = 1.94	LSR = 0.69	LSR = 0.80	LSR = 3.64

Table A29. Depth 70-80 cm.

Tmt	June	July	August	September	October
1	2.06 ± 0.66	1.14 ± 0.10	1.44 ± 0.34	0.95 ± 0.23	[a] 0.94 ± 0.18
2	6.34 ± 2.69	2.41 ± 0.50	1.23 ± 0.22	0.98 ± 0.15	[ab] 2.23 ± 0.38
3	2.48 ± 0.45	1.43 ± 0.17	0.94 ± 0.20	1.47 ± 0.25	[b] 4.17 ± 1.55
4	2.02 ± 0.71	1.97 ± 0.61	1.02 ± 0.13	1.76 ± 0.71	[ab] 1.88 ± 0.38
	LSR = 3.59	LSR = 1.92	LSR = 0.91	LSR = 1.81	LSR = 2.95

Table A30. Depth 80-90 cm.

Tmt	June	July	August	September	October
1	1.21 ± 0.18	1.43 ± 0.08	1.50 ± 0.38	0.86 ± 0.13	1.05 ± 0.11
2	1.87 ± 0.58	2.53 ± 0.88	0.92 ± 0.09	1.38 ± 0.28	1.65 ± 0.17
3	1.74 ± 0.27	2.02 ± 0.72	1.22 ± 0.22	1.24 ± 0.07	2.78 ± 0.79
4	1.91 ± 0.58	1.83 ± 0.23	0.88 ± 0.07	1.33 ± 0.06	1.43 ± 0.24
	LSR = 1.56	LSR = 1.82	LSR = 1.21	LSR = 0.54	LSR = 1.93

Table A31. Depth 90-100 cm.

Tmt	June	July	August	September	October
1	1.15 ± 0.22	1.60 ± 0.33	1.21 ± 0.36	1.06 ± 0.10	1.17 ± 0.21
2	2.39 ± 1.01	2.75 ± 0.42	0.92 ± 0.02	1.11 ± 0.17	1.30 ± 0.17
3	1.48 ± 0.16	1.79 ± 0.48	1.04 ± 0.28	1.27 ± 0.09	2.36 ± 0.55
4	2.14 ± 0.77	1.60 ± 0.15	0.82 ± 0.04	1.14 ± 0.04	1.48 ± 0.27
	LSR = 2.73	LSR = 1.59	LSR = 1.38	LSR = 0.58	LSR = 1.22

Tables A32-A41. Percent Kjeldahl nitrogen ($\overline{X} \pm SE$) in soil increments of 10 cm. from 0-100 cm. depth. Values sharing superscripts are not significantly different at the 0.05 level. LSR values from Tukey's test and are compared only within a time period and depth.

Table A32. Depth 0-10 cm.

Tmt	June	July	August	September	October
1	[a]0.120 ± 0.01	0.135 ± 0.01	0.142 ± 0.01	0.127 ± 0.02	0.122 ± 0.01
2	[b]0.165 ± 0.01	0.157 ± 0.01	0.157 ± 0.01	0.136 ± 0.01	0.122 ± 0.00
3	[ab]0.147 ± 0.01	0.162 ± 0.01	0.152 ± 0.01	0.150 ± 0.01	0.150 ± 0.02
4	[ab]0.140 ± 0.01	0.160 ± 0.01	0.157 ± 0.01	0.132 ± 0.01	0.122 ± 0.01
	LSR = 0.025	LSR = 0.040	LSR = 0.051	LSR = 0.082	LSR = 0.076

Table A33. Depth 10-20 cm.

Tmt	June	July	August	September	October
1	0.090 ± 0.02	0.130 ± 0.01	0.125 ± 0.01	0.125 ± 0.03	0.125 ± 0.01
2	0.107 ± 0.01	0.132 ± 0.01	0.130 ± 0.01	0.153 ± 0.01	0.137 ± 0.02
3	0.107 ± 0.02	0.142 ± 0.01	0.137 ± 0.01	0.135 ± 0.02	0.122 ± 0.02
4	0.102 ± 0.01	0.160 ± 0.01	0.135 ± 0.01	0.130 ± 0.01	0.107 ± 0.01
	LSR = 0.065	LSR = 0.056	LSR = 0.042	LSR = 0.094	LSR = 0.032

Table A34. Depth 20-30 cm.

Tmt	June	July	August	September	October
1	0.067 ± 0.01	0.070 ± 0.01	0.052 ± 0.01	0.061 ± 0.01	0.072 ± 0.01
2	0.077 ± 0.01	0.060 ± 0.01	0.095 ± 0.03	0.111 ± 0.02	0.100 ± 0.02
3	0.080 ± 0.02	0.077 ± 0.02	0.090 ± 0.03	0.082 ± 0.02	0.045 ± 0.00
4	0.075 ± 0.01	0.092 ± 0.01	0.065 ± 0.01	0.052 ± 0.01	0.092 ± 0.02
	LSR = 0.035	LSR = 0.070	LSR = 0.089	LSR = 0.094	LSR = 0.089

Table A35. Depth 30-40 cm.

Tmt	June	July	August	September	October
1	0.047 ± 0.01	0.037 ± 0.00	0.040 ± 0.01	0.038 ± 0.01	0.032 ± 0.01
2	0.045 ± 0.01	0.047 ± 0.01	0.040 ± 0.01	0.042 ± 0.01	0.040 ± 0.02
3	0.047 ± 0.01	0.052 ± 0.01	0.037 ± 0.01	0.050 ± 0.01	0.042 ± 0.01
4	0.035 ± 0.00	0.050 ± 0.01	0.045 ± 0.01	0.037 ± 0.01	0.032 ± 0.01
	LSR = 0.025	LSR = 0.043	LSR = 0.041	LSR = 0.050	LSR = 0.061

Table A36. Depth 40-50 cm.

Tmt	June	July	August	September	October
1	0.047 $\pm$ 0.01	0.035 $\pm$ 0.00	0.027 $\pm$ 0.01	0.026 $\pm$ 0.01	0.035 $\pm$ 0.01
2	0.030 $\pm$ 0.01	0.045 $\pm$ 0.01	0.035 $\pm$ 0.01	0.032 $\pm$ 0.01	0.027 $\pm$ 0.01
3	0.052 $\pm$ 0.01	0.032 $\pm$ 0.00	0.030 $\pm$ 0.01	0.032 $\pm$ 0.01	0.037 $\pm$ 0.01
4	0.035 $\pm$ 0.01	0.042 $\pm$ 0.01	0.042 $\pm$ 0.01	0.027 $\pm$ 0.01	0.027 $\pm$ 0.01
	LSR = 0.035	LSR = 0.027	LSR = 0.033	LSR = 0.038	LSR = 0.028

Table A37. Depth 50-60 cm.

Tmt	June	July	August	September	October
1	0.045 $\pm$ 0.01	0.025 $\pm$ 0.00	0.027 $\pm$ 0.01	0.028 $\pm$ 0.01	0.030 $\pm$ 0.01
2	0.032 $\pm$ 0.01	0.042 $\pm$ 0.01	0.037 $\pm$ 0.01	0.027 $\pm$ 0.01	0.030 $\pm$ 0.01
3	0.037 $\pm$ 0.01	0.027 $\pm$ 0.00	0.032 $\pm$ 0.00	0.027 $\pm$ 0.01	0.040 $\pm$ 0.01
4	0.042 $\pm$ 0.01	0.045 $\pm$ 0.01	0.045 $\pm$ 0.01	0.030 $\pm$ 0.01	0.030 $\pm$ 0.01
	LSR = 0.035	LSR = 0.031	LSR = 0.020	LSR = 0.036	LSR = 0.059

Table A38. Depth 60-70 cm.

Tmt	June	July	August	September	October
1	0.037 $\pm$ 0.01	0.035 $\pm$ 0.01	0.025 $\pm$ 0.01	0.027 $\pm$ 0.01	0.027 $\pm$ 0.01
2	0.030 $\pm$ 0.01	0.037 $\pm$ 0.01	0.045 $\pm$ 0.01	0.020 $\pm$ 0.01	0.025 $\pm$ 0.01
3	0.027 $\pm$ 0.01	0.027 $\pm$ 0.01	0.030 $\pm$ 0.01	0.032 $\pm$ 0.01	0.037 $\pm$ 0.01
4	0.032 $\pm$ 0.00	0.037 $\pm$ 0.01	0.030 $\pm$ 0.01	0.025 $\pm$ 0.01	0.025 $\pm$ 0.01
	LSR = 0.025	LSR = 0.025	LSR = 0.020	LSR = 0.022	LSR = 0.027

Table A39. Depth 70-80 cm.

Tmt	June	July	August	September	October
1	0.040 ± 0.00	0.032 ± 0.01	0.022 ± 0.01	0.023 ± 0.01	0.022 ± 0.01
2	0.035 ± 0.01	0.035 ± 0.01	0.035 ± 0.01	0.027 ± 0.01	0.022 ± 0.01
3	0.032 ± 0.01	0.027 ± 0.01	0.032 ± 0.00	0.037 ± 0.00	[a]0.037 ± 0.01
4	0.032 ± 0.01	0.037 ± 0.01	0.040 ± 0.01	0.020 ± 0.01	0.022 ± 0.01
	LSR = 0.025	LSR = 0.027	LSR = 0.022	LSR = 0.040	LSR = 0.011

Table A40. Depth 80-90 cm.

Tmt	June	July	August	September	October
1	0.027 ± 0.01	0.032 ± 0.01	0.020 ± 0.01	0.016 ± 0.00	0.012 ± 0.01
2	0.040 ± 0.01	0.035 ± 0.00	0.035 ± 0.01	0.030 ± 0.01	0.017 ± 0.01
3	0.030 ± 0.01	0.030 ± 0.01	0.025 ± 0.00	0.027 ± 0.01	0.030 ± 0.01
4	0.025 ± 0.01	0.037 ± 0.01	0.032 ± 0.01	0.017 ± 0.01	0.025 ± 0.01
	LSR = 0.017	LSR = 0.022	LSR = 0.022	LSR = 0.023	LSR = 0.022

Table A41. Depth 90-100 cm.

Tmt	June	July	August	September	October
1	0.025 ± 0.00	0.030 ± 0.01	0.020 ± 0.01	0.011 ± 0.01	0.025 ± 0.01
2	0.035 ± 0.01	0.027 ± 0.01	0.022 ± 0.01	0.022 ± 0.01	0.010 ± 0.01
3	0.027 ± 0.01	0.017 ± 0.00	0.027 ± 0.00	0.022 ± 0.01	0.023 ± 0.01
4	0.025 ± 0.00	0.030 ± 0.01	0.032 ± 0.01	0.022 ± 0.01	0.022 ± 0.01
	LSR = 0.023	LSR = 0.017	LSR = 0.019	LSR = 0.013	LSR = 0.027