Effect of Clipping, Fertilization and Water Stress on Species Composition of Experimental Plant Communities Along a Simulated Soil Gradient

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We performed two microcosm experiments to examine change in the structure of plant communities caused by clipping, water stress, and fertilization treatments along an artificially developed soil gradient. During the first experiment, we planted 15 cultivated and wild plant species on five soil textures having different sand and potting soil mixture proportions (i.e., 100:0, 75:25, 50:50, 25:75, 0:100) and disturbed them either by clipping at 5 & 10 cm height or through imposing water stress for a week. During the second experiment, we raised 19 cultivated and wild plant species and disturbed them by clipping at 5 cm height, by fertilization, and by both fertilization and clipping. The results indicated significant effects of soil textures and disturbances on stem density during both experiments, while biomass was significantly influenced by soil textures during the second experiment only. Disturbance types affected biomass, species richness and stem density during both experiments. The biplots of the biomass along the soil texture as environmental gradient indicated clustering of most of the species in the fertile sites during both experiments. Ordination of biomass along disturbance gradient as environmental variable indicated most of the species predominantly existing in the center with much preference to moderate clipping (10 cm height) during Experiment 1 and fertilization in Experiment 2. Partitioning of total explained variation showed maximum variation for disturbance types during Experiment 1, while in Experiment 2 soil textures comprised more variation. These microcosm experiments mimicked natural plant communities in many respects and proved helpful in understanding the impact of clipping, water stress and fertilization on the species composition along a simulated soil gradient.

INTRODUCTION

Understanding the dynamic changes in the species composition of plant communities with respect to different environmental gradients is considered vital to developing appropriate conservation plans. Edaphic factors that are never uniform throughout any landscape have particular bearing not only on the vigor and nature of individual plants, but also on the composition of the entire plant community (Fields et al 1999). Sometimes the variation of edaphic factors over very small distances is reflected in the form of abrupt changes in plant communities, such as those examined at steep hillsides, mouths of caves and mines, and at tip offs created either by tree fall or by burrowing animals (Fields et al 1999). In other instances, soil gradients change gradually resulting in the integration of different vegetation types and cannot be detected without proper analysis. Hence, edaphic factors have always been given special emphasis when classifying the vegetation types (Daubenmire 1952, USDA and NRCS 2000) and species composition of plant communities (Aude and Lawesson 1998, Seabloom et al, 1998, Leps et al 2000).

Abiotic stresses resulting from the deficiency of macro- and micronutrients in the soil and because of low soil moisture stress often produce low aboveground biomass levels per unit area. The survival of feeble species is also sometimes threatened under stress conditions which becomes a potential cause of drastic changes in the structure of plant communities. Such environmental gradients resulting from the shortage of resources ultimately support different combinations of adapted plant species (Stevens and Carson 2002). Some models (Crawley 1997, Ohmann and Spies 1998, Nicotra et al 1999, Kassen et al 2000) predict that such spatial heterogeneity in resource supply maintains high species richness by preventing competitive exclusion, arguing that different species perform differently in heterogeneous environments. Such patterns in plant species diversity along productivity gradients resulting from resource heterogeneity have been frequently tested (Gough et al 2000, Eek and Zobel 2001) but the issue yet remains controversial.

Disturbances also exert detrimental influences on the species composition of plant communities. Removal of the old growth creates new invading sites for recruits and increases the habitat breadth at productive sites. However, if disturbances are too low in their intensity they prove ineffective in controlling the competitive exclusion. Highly intense disturbances also sometimes threaten the survival of some species and yield to low richness (Barbara et al 2003). So determining the accurate intensity and frequency of disturbances, i.e., clipping and water stress, as well as, the effect of fertilization on species composition of plant communities, needs further experimentation.

In this study, we established a soil gradient to raise micro-communities incorporating some cultivated as well as wild plant species, which varied in their above ground biomass levels. We disturbed them by clipping, fertilizing and water stress to answer the following questions: (1) How does the species composition of experimental plant communities emerging from different soil textures vary in response to different clipping, fertilization and water stress treatments? (2) Do experimental plant communities exhibit any meaningful distribution patterns along soil textures and disturbance types? (3) Which factors comprise more variation in species biomass?

MATERIALS AND METHODS

During the first experiment, we developed a soil texture gradient by mixing sterilized sand and Perfect Mix All Purpose Potting Soil (Chemisco, Div. United Industries Corp, St. Louis, MO) in five different proportions. The sand to potting soil ratio for the five soil textures was as follows: T_0 (100:0), T_1 (75:25), T_2 (50:50), T_3 (25:75), T_4 (0:100). Table 1 presents the details of the chemical analysis of soil textures conducted by Brookside Laboratories Inc. (New Knoxville, OH).

For each treatment, we filled in 32 plastic pots measuring 10 cm x 10 cm x 5 cm for a total of 160 pots. On May 11, 2004, we arranged all the pots in a completely randomized design on the laboratory tables at room temperature (25 °C). In each pot, we broadcasted five seeds of each of 11 wild and cultivated plant species (Table 2) obtained from the seed store of Stillwater Flour Mills (Stillwater Milling Company, Stillwater, Oklahoma). The number of large-sized seeds was counted manually while the number of those having a small size was worked out on a weight basis. After planting the seeds, we covered them with a thin layer of the same textured soil as above and watered with a sprinkler. On 11 June 2004, we disturbed the plant communities through the following four disturbance treatments each applied to eight already randomly selected and earmarked pots: control (D_0), clipping at 5 cm height (D_1), clipping at 10 cm height (D_2), and water stress—withheld watering for one week (D_3).

On July 9, we harvested plants near the soil surface, counted the number of stems for each species in each pot and packed them separately in paper bags. We dried

Table 1. Soil textures and their chemical attributes.

	Soil textures (sand:soil)				
Parameter	T0 (100:0)	T1(75:25)	T2 50:50)	T3(25:75)	T4(0:100)
pH	7.95	7.00	6.75	6.35	5.90
Organic Matter	0.18	1.32	4.37	13.82	71.10
Soluble Sulfur	19.50	21.50	23.50	49.00	43.50
P_ppm	16.00	23.50	33.00	41.00	73.00
Ca_ppm	1923.00	2340.50	2449.50	2023.50	2029.50
Mg_ppm	72.00	88.00	105.00	123.50	216.00
K_ppm	35.00	61.50	93.50	129.00	230.00
Na_ppm	19.00	33.00	50.00	153.50	210.00
Ca_pct	92.60	91.90	90.20	83.40	52.30
Mg_pct	5.81	5.78	6.45	8.53	9.28
K_pct	0.87	1.25	1.77	2.76	3.03
Na_pct	0.81	1.135	1.61	5.35	4.83
H_pct	0.00	0.00	0.00	0.00	30.57
B_ppm	0.51	0.64	0.65	0.70	0.84
Fe_ppm	34.00	50.50	72.50	86.50	189.00
Mn_ppm	8.50	10.50	14.00	19.00	30.50
Cu_ppm	0.56	0.70	0.80	1.43	2.29
Zn_ppm	1.71	4.03	2.90	6.40	10.32
Al_ppm	43.50	37.00	45.00	81.50	154.00

Table 2. List of plant species sown during Experiment 1.

Botanical name	Common name	Family
Brassica juncea	turnip	Brassicaceae
Chrysanthemum leucanthemum	oxeye daisy	Asteraceae
Festuca sp	fescue (creeping red)	Poaceae
Lomatium nuttallii	moss curled parsley	Apiaceae
Melilotus officinalis	yellow sweet clover	Fabaceae
Ratibida columnifera	prairie coneflower	Asteraceae
Rudbeckia hirta	black eyed susan	Asteraceae
Solanum melongena	black beauty eggplant	Solanaceae
Triticum aestivum	wheat	Poaceae
Vigna sinensis	cowpea	Fabaceae
Zea mays	sweet corn	Poaceae

the plant samples in an oven at 35 °C until they reached constant weight and weighed them by a Sartorius electric balance.

For Experiment 2, we established the same five soil textures by using fresh potting soil mixture and sterilized sand. However, during this experiment, we planted 16 plant species (Table 3) in each pot on July 14, 2004. The following disturbance treatments were applied on August 30, 2004: control (D_0), clipping at 5 cm height (D_1), fertilization (D_2), fertilization and clipping at 5 cm height (D_3). For fertilization treatment I used Miracle Gro Liquid All Purpose Plant Food (Scotts Miracle Gro Products Inc.,

Table 3. List of plant species sown during Experiment 2.

Botanical name	Common name	Family
Abutilon theophrasti	velvet leaf	Malvaceae
Aeschynomene virginica	northern jointvetch	Fabaceae
Amaranthus retroflexus	redroot pigweed	Amaranthaceae
Anoda cristata	spurred anoda	Malvaceae
Brassica juncea	turnip	Brassicaceae
Chenopodium album	common lambsquarters	Chenopodiaceae
Digitaria sanguinalis	large crabgrass	Poaceae
Erisimum repandum	bushy wallflower	Brassicaceae
Lomatium nuttallii	moss curled parsley	Apiaceae
Melilotus officinalis	yellow sweet clover	Fabaceae
Setaria faberi	giant foxtail	Poaceae
Senna obtusifolia	sicklepod	Fabaceae
Sesbania exaltata	hemp sesbania	Fabaceae
Solanum melongena	egg plant	Solanaceae
Sorghum halepense	johnson grass	Poaceae
Triticum aestivum	wheat	Poaceae

Scottslawn Road Marysville, OH) at the recommended rate. We harvested the plants at soil surface on September 30, 2004, then after sorting, counting, and drying them separately, recorded their dry weights.

Statistical Analysis

We analyzed the biomass data by using general linear model (univariate) in SPSS (Statistical Package for the Social Sciences, SPSS Inc, 233 South Wacker Drive, 11th Floor, Schicago, IL) to determine the effect of soil types and disturbances on the above ground biomass of micro-communities. We applied Duncan's new multiple range test for the pos-hoc comparisons among soil types and disturbance types. Figures were constructed by using Microsoft Excel to graphically represent the mean biomass values and their confidence intervals (95%) pertaining to soil textures and disturbance types.

To examine the distribution pattern of plant species biomass (square root transformation) we performed a series of Partial Constrained Correspondence Analysis (pCCA) models (ter Braak 1986) which decompose the variance in the response variables into independent components (Borcard et al 1992, Okland and Eilertsen 1994). Through pCCA, we determined the variation explained by soil textures (environmental variables) after the variation associated with disturbance types (covariables) had been removed and vice versa. We tested all the pCCA models by using a Monte Carlo permutation approach. For the interactive effects of soil textures and disturbance types, we performed Canonical Correspondence Analysis (CCA) as well.

RESULTS

Effect of soil textures and disturbance types on species biomass, stem density and richness (SPSS analysis)

Experiment 1

Soil texture significantly affected species richness and stem density, but not significantly the above ground biomass, while disturbances caused significant influence on all these parameters of micro plant communities (Table 4). The interactive effects of soil textures and disturbances types were, however, statistically not significant. The efficacy of different disturbances in removing the biomass levels efficacy may be ranked

Table 4. Effect of soil texture and disturbance on the aboveground biomass, species richness and stem density of micro-plant communities, (*P*<0.01).

Source	Sum of Squares	df	Mean Square	F	*P* Value
Experiment 1—Biomass					
Textures	0.611	4	0.153	0.179	0.949
Disturbances	391.274	3	130.425	152.965	0.000
Textures x Disturbances	9.789	12	0 .816	.957	0.493
Stems					
Textures	4120.963	4	1030.241	16.999	0.000
Disturbances	1908.969	3	636.323	10.499	0.000
Textures x Disturbances	1306.937	12	108.911	1.797	0.054
Richness					
Textures	220.475	4	55.119	28.807	0.000
Disturbances	62.869	3	20.956	10.952	0.000
Textures x Disturbances	39.475	12	3.290	1.719	0.069
Experiment 2—Biomass					
Textures	2.738	4	0 .685	4.553	0.002
Disturbances	26.080	3	8.693	57.818	0.000
Textures x Disturbances	2.207	12	0.184	1.223	0.273
Stems					
Textures	1135.088	4	283.772	5.548	0.000
Disturbances	1973.276	3	657.759	12.861	0.000
Textures x Disturbances	885.692	12	73.808	1.443	0.153
Richness					
Textures	13.104	4	3.276	1.497	0.206
Disturbances	65.200	3	21.733	9.930	0.000
Textures x Disturbances	47.895	12	3.991	1.824	0.050

as clipping (5 cm height)>clipping (10 cm height)>water stress>no disturbance (Table 5). While comparing the stem density among different soil textures, we noted that, with the exception of T_0 and T_1 in the remaining soil textures, stem density gradually increased with the improvement in the organic matter. For disturbance types, clipping at 10 cm height yielded to maximum stem density. Species richness of experimental plant communities indicated a resembling trend along "soil textures" and "soil texture and disturbance" gradients.

Experiment 2

We examined the effects of soil textures, as well as disturbance types on the biomass of macro-plant communities (Table 4). It seems that gradual improvement in soil texture simultaneously resulted in an increase in biomass levels (Table 6). During this phase of the experiment, we recorded the least biomass for clipping at 5 cm height and the maximum biomass for the fertilized pots. The biomass levels for the fertilization treatment and disturbance types may be ranked as fertilization>clipping (10 cm height) and fertilization>no clipping>clipping (10 cm height).

Both soil textures and disturbance types significantly influenced the number of stems. While comparing the soil textures, we examined a gradual increase in stem density with the improvement in soil texture, particularly in T_3 and $T_{4,}$ that differed significantly from control. All the three

Table 5. Mean biomass, stems and species richness values as affected by soil texture and disturbances, ($P<0.01$).

Treatment No.	Experiment 1 Biomass	Experiment 1 Stems	Experiment 1 Richness	Experiment 2 Biomass	Experiment 2 Stems	Experiment 2 Richness
T_0	2.42 a	28.34 b	7.63 b	0.88 a	23.06 a	7.94 a
T_1	2.37 a	23.34 a	6.44 a	0.91 ab	23.88 a	7.41 a
T_2	2.43 a	37.31 c	9.28 cd	1.08 ab	25.97 ab	7.31 a
T_3	2.37 a	34.62 c	8.81 c	1.24 c	30.13 c	7.88 a
T_4	2.54 a	34.47 c	9.63 d	1.08 bc	28.81bc	7.97 a
D_0	0.65 a	34.38 c	8.75 bc	1.00 b	31.67 c	8.49 c
D_1	1.12 b	30.35 b	8.28 b	0.56 a	26.76 b	7.68 b
D_2	3.71 c	35.20 c	8.75 c	1.69 c	25.35 b	7.92 bc
D_3	4.24 d	26.55 a	7.38 a	0.89 b	21.83 a	6.73 a

disturbances caused significant reduction in the stem density. We examined the lowest stem density in clipping and fertilization followed by fertilized (D_2) and clipped (D_1) communities. However, the difference in the biomass of clipped communities and fertilized communities was not significant. Species richness was significantly influenced by disturbance treatments only. We observed maximum species richness for the fertilized communities, which differed non-significantly from control (no disturbance) as well as from clipped communities while minimum species richness turned out for the communities receiving both clipping and fertilization. It seems that the severe effects of clipping could not be compensated even by fertilization.

MULTIVARIATE ANALYSIS (pCCA & CCA)

Experiment 1

The pCCA of the biomass data with respect to soil texture as an environmental variable and disturbance types as a covariable indicated highly significant variation ($P<0.01$, eigenvalue 0.018) along axis 1 (Table 6). A biplot of species biomass and soil textures as environmental variable (Fig. 1a) revealed clustering of most of the species around $T_{3,}$ on the left side of first axis while *Lomatium, Festuca,* and *Melilotus* dominantly existed in T_4. Species biomass data showed significant ($P<0.005$) variation in response to disturbance types as well. Most of the species become clustered in the centre (Fig. 1b). However, *Zea* and *Vigna* showed high sensitivity to clipping so they predominantly existed either in control or water stress treatment while *Lomatium, Festuca, Brassica, Triticum,* and *Ratibida* were common in low intensity disturbance (D_2)

Experiment 2

During this phase of study, CCA of biomass showed significant ($P<0.005$) variation in respect to both environmental variables (soil types and disturbances). The ordination of species data along the soil textures as environmental variable and disturbance types as covariable indicated that *Amaranthus* was encountered dominantly in the sandy soil shown at the right side of Axis 1 and *Solanum* toward T_4 at the left extreme of the first axis (Fig. 2a). *Sorghum* predominantly existed in $T_{2,}$ while the remaining species were skewed towards the left side of the axis showing a little bias towards T_1 and T_3.

The biplot of species biomass along the disturbance gradient as environmental variable and soil texture as covariable revealed *Sesbania* and *Melilotus* dominantly occurring

Table 6. Results of multivariate analysis of species distribution using species data (biomass and stem counts), with respect to soil texture and disturbance data (both as environmental variables and covariables)(pCCA), CCA for the interactive effects of soil textures and disturbance types. (*P*<0.01).

	Axis			
Parameters and data	1	2	Total inertia	*P* value
Experiment 1				
pCCA				
a. Biomass (Texture | Disturbance).				
Eigenvalues	0.018	0.009	0.421	0.002
Sum of all canonical eigenvalues	0.033			
b. Biomass (Disturbance | Texture).				
Eigenvalues	0.111	0.005	0.421	0.002
Sum of all canonical eigenvalues	0.117			
a. Stems (Texture | Disturbance).				
Eigenvalues	0.031	0.022	0.438	0.002
Sum of all canonical eigenvalues	0.065			
b. Stem (Disturbance | Texture).				
Eigenvalues	0.020	0.004	0.438	0.002
Sum of all canonical eigenvalues	0.026			
CCA				
Interactive effect of soil textures and disturbance types on species biomass.				
Eigenvalues	0.117	0.074	1.060	0.002
Sum of all canonical eigenvalues	0.178			
Experiment 2				
pCCA				
a. Biomass (Texture | Disturbance).				
Eigenvalues	0.065	0.017	1.060	0.002
Sum of all canonical eigenvalues	0.094			
b. Biomass (Disturbance | Texture).				
Eigenvalues	0.039	0.020	1.060	0.002
Sum of all canonical eigenvalues	0.059			
a. Stems (Texture | Disturbance).				
Eigenvalues	0.071	0.009	0.903	
0.002				
Sum of all canonical eigenvalues	0.090			
b. Stem (Disturbance | Texture).				
Eigenvalues	0.036	0.025	0.903	0.002
Sum of all canonical eigenvalues	0.071			
CCA				
Interactive effect of soil textures and disturbance types on species biomass.				
Eigenvalues	0.124	0.022	0.401	
Sum of all canonical eigenvalues	0.333			

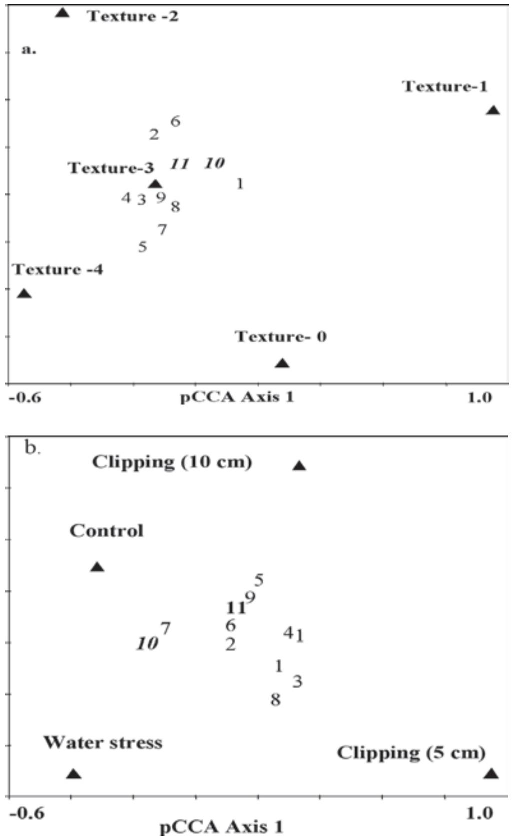

Figure 1. pCCA of species biomass during Experiment 1, (a) Axis 1 related to soil textures, (b) Axis 1 associated with disturbance gradient, species indicated by numbers (10 & 11 in boldface) along with small triangles and large triangles indicate soil textures and disturbance types. *Brassica juncea* (1), *Chrysanthemum leucanthemum* (2), *Festuca* sp. (3), *Lomatium nuttallii* (4), *Melilotus officinalis* (5), *Ratibida columnifera* (6), *Rudbeckia hirta* (7), *Solanum melongena* (8), *Triticum aestivum* (9), *Vigna sinensis* (10), *Zea mays* (11).

in the nondisturbed pots (D_0) and *Digitaria* in the disturbed and fertilized pots (D_2; Fig. 2b). The remaining species, clustered in the center, seem equally affected by all clipping and fertilization treatments.

Interactive effects of soil textures and disturbance types (CCA)

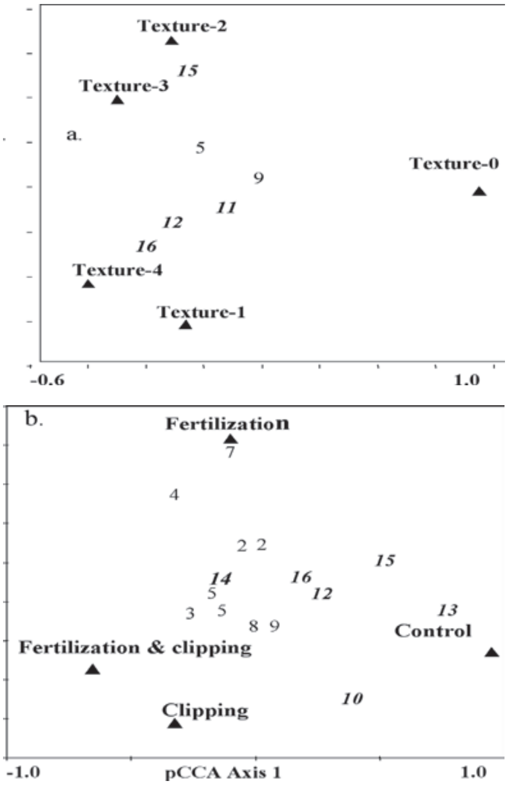

Figure 2. pCCA (a) Biomass of species along axis 1 for soil textures, (b) Biomass along Axis 1 as disturbance gradient, species indicated by numbers alongside small triangles, while large triangles indicate soil textures and disturbance types. *Abutilon theophrasti* (1), *Aeschynomene virginica* (2), *Amaranthus retroflexus* (3), *Anoda cristata* (4), *Brassica juncea* (5), *Chenopodium album* (6), *Digitaria sanguinalis* (7), *Erisimum repandum* (8), *Lomatium nuttallii* (9), *Melilotus officinalis* (10), *Setaria faberi* (11), *Senna obtusifolia* (12), *Sesbania exaltata* (13), *Solanum melongena* (14), *Sorghum halepense* (15), and *Triticum aestivum* (16).

In Experiment 1, CCA of species biomass indicated the highest variation along Axis 1 (Table 6). A joint plot of species and interactive effects of soil textures and disturbance types indicated a close association between the species keeping high carbohydrate reserves (*Vigna, Zea*) to comparatively more fertile and undisturbed soil textures (T_4D_0) and those receiving water stress treatment (T_4D_3; Fig. 3a). The remaining species showed more biasness towards clipping at 10 cm with no discrimination for soil textures located in the center.

During Experiment 2 (through CCA) we noted significantly higher variation in species biomass along Axis 1 (Table 6). The joint plot of species and interactive effects of soil textures and disturbance types showed a close link between two leguminous species (*Sesbania* and *Melilotus*) and undisturbed pots with intermediate fertility levels (T_3D_0, T_2D_0; Fig 3b). *Digitaria,* an outlier species showed close association with fertilized sandy soil being located in the right top corner. The remaining plant species, with the exception of *Erigeron* and *Amaranthus,* were concentrated in the center showing more biasness to fertilized pots.

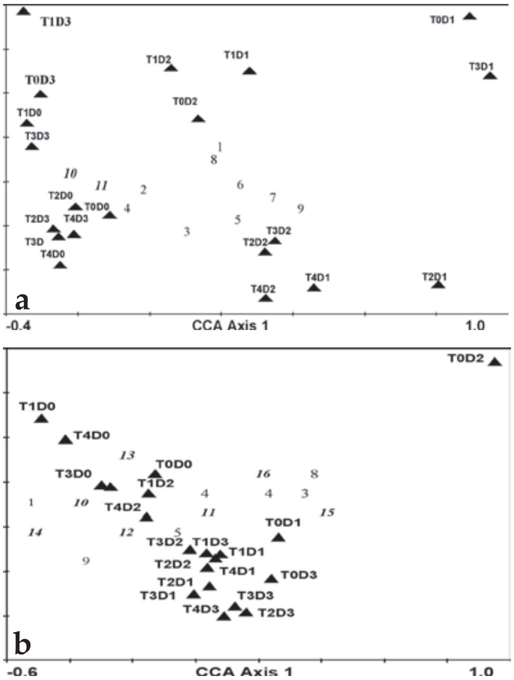

Figure 3. Interactive effect of soil textures and disturbance types, a) Experiment 1, b). Experiment 2, species indicated by number along with small triangles, large triangles indicate the interactive terms, i. e., T_0D_0 (Texture-0 x control), T_1D_0 (Texture-1 x control), T_2D_0 (Texture-2 x control), T_3D_0 (Texture-3 x control), T_4D_0 (Texture-4 x control), T_5D_0 (Texture-5 x control), T_0D_1 (Texture-0 x clipping-5 cm), T_1D_1 (Texture-1 x clipping-5cm), T_2D_1 (Texture-2 x clipping-5 cm), T_3D_1 (Texture-3 x clipping-5 cm), T_4D_1 (Texture-4 x clipping-5cm), T_5D_1 (Texture-5 x clipping-5 cm), T_0D_2 (Texture-0 x clipping-10 cm), T_1D_2 (Texture-1 x clipping-10 cm), T_2D_2 (Texture-2 x clipping-10 cm), T_3D_2 (Texture-3 x clipping-10 cm), T_4D_2 (Texture-4 x clipping-10 cm), T_5D_2 (Texture-5 x clipping-10 cm), T_0D_3 (Texture-0 x Water stress), T_1D_3 (Texture-1 x Water stress), T_2D_3 (Texture-2 x Water stress), T_3D_3 (Texture-3 x Water stress), T_4D_3 (Texture-4 x Water stress), T_5D_3 (Texture-5 x Water stress).

DISCUSSION

We conducted three microcosm experiments to examine the effect of clipping, fertilizing, and water stress treatments on the species composition of plant communities raised on five different soil textures varying in the proportion of sand and potting soil mixture. In Experiment 1, we disturbed one-month-old microplant communities comprising 15 cultivated and weedy species either through clipping at 5 and 10 cm height or by imposing water stress for 1 wk. The two-way analysis of species biomass indicated significant influence of disturbance types only. The biomass levels among difference soil textures differed non-significantly, perhaps due to homogenization of their fertility. Nevertheless, both soil textures, as well as disturbance types significantly influenced species richness and stem density. Clipping at 5 cm height proved more effective in reducing the biomass level followed by clipping at 10 cm height. It indicates that the effectiveness of disturbance types in removing the biomass levels depended upon the height of clipping. As compared to other disturbance types, water stress proved least effective in reducing the biomass, but it also varied significantly from control.

Stem density and species richness of experimental communities showed a resembling response to soil textures and disturbance types. Soil textures having higher stem density had higher species richness as well. The least number of stems and species in water stressed pots during Experiment 1 as well as Experiment 3 indicates that it caused permanent wilting and mortality of some weak individuals and turned to low species richness, while the water stress resistant individuals belonging to species having high carbohydrate reserves regained their vigor at the termination of stress. The availability of more resources for the fewer surviving individuals may be another reason for maximum biomass level in water stressed pots. In contrast, severe disturbance (clipping at 5 cm height) seems to have resulted in the mortality of some individuals and turned to low stem density and species richness. It appears that following severe disturbance the victim/disturbed plants were unable to regenerate and gain high biomass levels under a strong competitive environment for limited resources. Calcareous fen vegetation in southern Germany responded to grazing and mowing in a similar way, and species richness was significantly reduced due to intense grazing disturbance (Barbara et al 2003).

It seems clipping at 10 cm height proved less intense and might have caused slight damage to the canopy of many individuals, which could not confer their mortality. Consequently, after quick regeneration they not only returned to higher biomass levels, but also to significantly higher stem density and, species richness. These results support the view that mowing and hay removal regulate species richness not only through competitive exclusion but also in many other ways (Schaffers 2002).

During the second experiment both factors (soil textures and disturbance types) significantly affected biomass, stem density, and species richness of micro-communities. Despite a slight variation, we examined a gradual increase in all the three parameters with the improvement in soil texture, i.e., low sand content and high content of potting soil mix. While comparing clipping and fertilizing treatments, we found that clipping at 5 cm height not only reduced biomass levels, but also caused the mortality of some individuals and turned to low richness as that examined during Experiment 1. The regeneration failure of some species also profoundly changed species composition as already examined by West et al (2000) in subtropical forest vegetation. Fertilization, however, improved the biomass level due to availability of more resources and for not causing any damage to plants. Hence, it returned to higher stem density and species richness as compared to clipping treatments.

Despite fertilization, plants species growing on very limited resources even in fertilized pots did not gain such high biomass levels, which could cause competitive exclusion as previously examined by Stevens and Carson (2002). Similar results have been observed for natural communities during some earlier studies by the addition of nutrients that showed significant positive effects on biomass production but did not cause significant change in species richness or community composition attributable to competitive exclusion (Chiarucci et al 1999, Eek and Zobel 2001).

The CCA results confirmed the SPSS results, revealing significant effects of soil textures on biomass during the second experiment only, while disturbance types significantly influenced it during both experiments. Stem density was, however, significantly affected by soil textures as well as disturbance types during both experiments. The biplot of species biomass data along the soil texture gradient indicated clustering of a majority of the species around $T_{3,}$ which had sand to soil ratio 25:75. A similar trend was recorded during a study conducted by Clark et al (1999) relating to tropical rain forest trees. The biplot of species biomass against disturbance gradient as environmental variable and soil textures as covariable indicates a majority of species occurring in pots clipped at 10 cm height (D_2) in Experiment 1. In Experiment 2 as well, most of the species seem clustered around fertilization (D_2) indicating the preference of species for undisturbed sites having more nutrients. The poor turnover of species at disturbed sites (clipping at 5 cm height) may be due to the severity of disturbance and shortage of nutrients in the pots having high sand content.

In summary, the micro-communities mimicked natural communities in many respects and proved an effective experimental tool to examine the change in species composition along a soil gradient under the influence of clipping, fertilization and water stress treatments. These micro-communities can prove very helpful for testing the effect of specific environmental factors. The fuzziness or complexity created by different interacting factors can also be resolved very effectively through such microcosm experiments.

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