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Tall Fescue Production and Nutrient Status on Southwest Virginia Mine Soils

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ABSTRACT

Tall fescue (*Festuca arundinacea* Schreb.) is a hardy grass species commonly used in surface mine reclamation and soil conservation. This study documented changes in fescue production (five growing seasons) and nutrient status (three growing seasons) as influenced by spoil type and various amendments. In Exp. I, fescue growth and nutrient status on five mixes of fertilized sandstone (SS) and siltstone (SiS) spoils were compared. A 2:1 SS/SiS control and treatments of 112 Mg ha^{-1} sawdust, native topsoil, and 22, 56, 112, and 224 Mg ha^{-1} municipal sewage sludge were compared in Exp. II. Standing biomass was measured in 1982–1984 and 1986 and tissue nutrient levels were measured in 1982–1984. High SiS spoils inhibited initial biomass production in Exp. I, but parent material effects diminished with time. All spoil mixes maintained adequate fescue production for five growing seasons, primarily due to small annual N additions (56 kg ha^{-1}). In Exp. II, highest yields were maintained on $\geq$56 Mg ha^{-1} sludge treatments. Fescue production declined consistently through 1984 in all other treatments, probably due to N stress. Fescue production was highest the second year (1983) in all treatments of both experiments, but dropped sharply in 1984. Overall results indicate N was most limiting to production in the short term, but P becomes limiting over time. Sludge-amended soils supported higher N, P, and cation tissue concentrations. Total P uptake appeared to be limited by low N levels, even when adequate soil P was available. potassium uptake rates greatly exceeded K fertilizer applications. Heavy metal uptake was not a problem, even in very high sludge treatments. Sludge-amended mine soils were superior to both native topsoil and inorganically fertilized spoils in their ability to sustain long-term fescue production without periodic augmentation.

Additional Index Words **Reclamation, Revegetation, Mine spoil, Topsoil, *Festuca arundinacea* Schreb.**

The major goals of surface mine revegetation are to reduce erosion, stabilize the mine soil, and produce a site suitable for the desired postmining land use. Herbaceous vegetation is frequently used to provide a suitable green manure for agricultural or horticultural crop production (Opeka and Morse, 1979; Jones et al., 1975). In the Appalachians, intensive postmining land uses are less common, and herbaceous cover is commonly used as a site conditioner for forest management (Vogel, 1981), or as stabilizing cover for the enhancement of natural sucession and development of wildlife habitats (Rafaill and Vogel, 1978). The Surface Mining Control and Reclamation Act of 1977 (SMCRA—PL 95-87), and resultant state regulations require establishment of a permanent, self-sustaining vegetative community that persists for 5 yr for bond release. Usually at least 90% ground cover must persist through the period. Seeding and fertilizer augmentation are not allowed during this 5-yr period unless the land is permitted to agricultural land uses. 'Kentucky-31' tall fescue (*Festuca arundinacea* Schreb.) is the most commonly used reclamation grass in the Appalachians becuase of its tolerance to a wide range of site conditions. Documentation of changes in fescue production and nutrient status during the 5-yr bond period is essential to develop new, more efficient reclamation stratagies that do not rely on excessively large inorganic fertilizer additions.

Little is known of the specific affects of mine spoil types, fertilization, and organic amendments on the establishment of a permanent, self-sustaining tall fescue stand for multiple growing seasons. Reported concentration ranges of selected elements in tall fescue compiled from other studies are given in Table 1. The reported ranges for most elements are considerable and reflect differences in soils, geology, fertilization, and amendments.

Fertilization and geological factors strongly affected fescue growth on spoils from the Warrior Basin of northern Alabama (Weisenfluh et al., 1981). Fescue growth varied with parent material as follows: shale > siltstone > mixed spoils > sandstone = conglomerate. Fertilizer treatments were ranked NPK = NP $\gg$ N> control, which implicated P as the primary limiting factor. They concluded that the use of weathered spoils was detrimental to plant growth and that they should not be used as topsoil substitutes.

The suitability of various cool-season grasses for reclamation of surface mine coal spoils in western Kentucky was reported by Powell et al. (1982). Spring seeded KY-31 tall fescue production ranked first (3.7 Mg ha^{-1}) and third (4.0 Mg ha^{-1}) of 33 treatments in 1979 and 1980 when seeded alone and was 25% higher than fall-seeded fescue. When tall fescue was seeded with legumes in the spring, the combination ranked second (4.4 Mg ha^{-1}) and first (5.9 Mg ha^{-1}) in 1979 and 1980 of 33 treatments. yields increased the second year in all planting and species combinations.

Table 1. Ranges of reported tissue concentrations of selected elements in tall fescue.

Elements	Concentration range	References†
	—— g kg^{-1} ——	
Macronutrients		
N	9.5–27.3	A,C,D,F
P	1.3–6.2	A,B,C,D,F
K	11.8–40.0	A,B,C,F
Ca	2.7–14.8	A,B,C,D.F
Mg	1.5–5.1	A,B,C,D,F
Heavy metals	— mg kg^{-1} —	
Fe	48–645	B,D,F
Mn	51–593	B,D,E,F
Zn	10–96 (3365)‡	A,B,D,E,F
Cu	2–46 (738)‡	A,B,D,E,F
Cd	<1–5 (275)‡	E

† A = Seaker and Sopper, 1984; B = Hanson et al., 1982; C = Powell et al., 1982; D = Reid et al., 1970; E = Boswell, 1975; F = Baker and Reid, 1977.

‡ These are the highest reported values by Boswell (1975), but are not typical concentration ranges for these metals.

Sludges, paper mill wastes, sawdust, and other organic

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amendments have been utilized as alternative amendment materials on mine soils in lieu of standard fertilizers. Sludges can alleviate nutrient deficiencies in mine soils and reduce acid formation (Halderson and Zenz, 1978). However, metal contents may eliminate certain sludges from being considered for use in reclamation (USEPA, 1983). Seaker and Sopper (1984) reported results for sites limed at 8.4 Mg ha^{-1} and amended with various sludges. The sites were seeded with a grass/legume mixture containing tall fescue, and yields increased the first 4 yr of the study before a fifth year decrease. Tall fescue N, P, K, Ca, and Mg tissue concentrations were higher on in sludge-amended soils. Metal concentrations were highest in tall fescue growing on spoils with the lowest pH. While sludge application often increased tissue concentrations of metals, these levels did not exceed plant tolerance levels.

In another sludge rate study on mine spoils, Haghiri and Sutton (1982) found that fescue yields increased between 1977 and 1978, but then decreased in 1979. This yield decrease was attributed to depletion of the readily mineralizable portion of the sludge organic-N. Plant tissue N contents decreased between 1978 and 1979 as a result of reduced N availability. Plant tissue Cd, Cu, Fe, Mn, and Zn concentrations decreased on all sludge treatments between 1977 and 1979. The authors concluded that increased soil pH and organic matter content from sludge application caused fixation and immobilization of heavy metals.

The objective of this study was to assess growth and nutritional factors that affect the growth of KY-31 tall fescue on new mine soils weathering from different topsoil substitute rock spoils in Exp. I, and on fescue performance in relation to topsoil and organic additions in Exp. II. Behavior of tall fescue as a conservation species is much different from when it is grown and harvested as a forage crop, particularly with regards to long-term nutrient accumulation and cycling. Therefore, documentation of changes in fescue production and nutritive status over multiple seasons is critical to development of effective long-term revegetation strategies.

MATERIALS AND METHODS

Changes in mine soil properties across time in two experiments in southwestern Virginia, as well as details of geology, site conditions, and experimental design are given by Roberts (1986). Experiment I was seeded on five spoil mix combinations that ranged from sandstone (SS) to siltstone (SiS) with intermediate rock mixes of 2:1, 1:1, and 1:2 parts SS/SiS. Experiment II was seeded over a constant 2:1 SS/SiS spoil mix with a control and six other surface-applied treatments. These treatments were 112 Mg ha^{-1} sawdust, 30 cm of local "topsoil" (mixed A + E + B + Cr horizons), and 22, 56, 112, or 224 Mg ha^{-1} (dry) aerobically digested municipal sewage sludge. Nitrogen, P, and K additions from the sludge are summarized in Table 2, along with other treatment inputs for both experiments. The sludge contained 37 g Ca, 3.8 g Mg, 320 mg Mn, 880 mg Zn, 245 mg Cu and 6 mg Cd kg^{-1} at application.

Table 2. Total N, P, and K added as chemical fertilizer (treatments 1–3) and added in municipal sewage sludge (treatments 4–7) in Exp. II.

Treatment	N	P	K
	kg ha^{-1}		
1. Control†	168	147	137
2. Topsoil + lime	168	147	137
3. Sawdust (112 Mg ha^{-1})	504‡	147	137
4. Sewage sludge (22 Mg ha^{-1})	582	29	56
5. Sewage sludge (56 Mg ha^{-1})	1455	74	140
6. Sewage sludge (112 Mg ha^{-1})	2910	147	280
7. Sewage sludge (224 Mg ha^{-1})	5820	295	560

† These values also indicate initial N, P, and K additions in all Exp. I treatments. Each treatment received 56 kg N ha^{-1} as NH_4NO_3 in the fall of each year of the study for an accumulated N rate of 392 kg N ha^{-1}.
‡ Includes 336 kg N ha^{-1} added as slow-release IBDU fertilizer.

Experiment I received a uniform application of 168 kg ha^{-1} N, 147 kg ha^{-1} P, and 137 kg ha^{-1} K as NH_4NO_3, $(NH_4)_2HPO_4$, and KCl. All plots in Exp. I also received an additional 56 kg N ha^{-1} each fall (1982–1985) to simulate legume additions. Legumes were not used in this research so that vegetation type would remain constant across all treatments. The control treatment in Exp. II was treated identically to all treatments in Exp. I, except for the annual N additions. The spoils used in the experiments initially ranged in pH from 5.5 (SS) to 7.5 (SiS). The topsoil material was quite acidic (pH 4.4), and topsoiled plots received 7.8 Mg agricultural lime ha^{-1} to bring pH up to that of the spoils and also received fertilizer. The sawdust plots received the base fertilizer rate plus 336 kg ha^{-1} of slow-release N (Isobutyl Di-Urea; IBDU) to offset microbial immobilization. Sludge plots received no inorganic fertilization. All plots were seeded to KY-31 tall fescue (80 kg ha^{-1}) and straw mulched (2700 kg ha^{-1}) in May 1982. Invading legumes and broadleaved species were eliminated with herbicide each year. Both experiments were arranged as randomized complete block designs with four replications.

Each 3.5 × 3.5 m main plot was gridded into 0.1 m^2 quadrats for sampling. Two quadrats were randomly selected each year and the soil and vegetation were sampled in October 1982, 1983, 1984, and vegetation only in 1986. The plots were not sampled in 1985; however, they were examined visually and exhibited similar fescue growth response to 1984. In this paper we report fescue yield data through the fifth growing season (1986), and soil and tissue nutrient levels for the first three growing seasons (1982–1984). Aboveground biomass was sampled to ground level by hand clipping, and included a small amount of standing litter from previous years. Vegetation was removed only from the sampled quadrats, and was never clipped on the remainder of the plot. Sampled quadrats and immediately adjacent quadrats were excluded from sampling location selection in future years. Thus, the quadrats sampled in each year were completely undisturbed since seeding, and the samples represent all aboveground standing biomass at that time.

Dry weight of standing biomass was determined after oven-drying at 65 °C for 48 h. Dried tissue was ground to pass a 1-mm screen in a stainless steel Wiley Mill. Tissue was digested with HNO_3–$HClO_4$ and Ca, Mg, K, Fe, Mn, and Zn concentrations in the digests were measured by atomic absorption spectrophotometry. Cadmium and Cu concentrations were determined by flameless atomic absorption spectrophotometry. Soil pH was measured in the supernatant of a 1:1 soil/water slurry, and available soil P was estimated by extraction in 0.5 M $NaHCO_3$ at pH 8.5. Total N was determined colormetrically after Kjeldahl digestion by the method of Bremner and Mulvaney (1982). Tissue and soil extract P were determined by the method of Murphy and Riley (1962). Soil CEC was taken as the sum of pH 7 M NH_4OAc exchangeable Ca, Mg, K, and Al. All soil analyses were performed on the < 2-mm fraction, which initially comprised 24% (SiS) to 38% (SS) of the spoils used. Treatment variations in the parameters measured within years were analyzed by a least squares method analysis of variance procedure. Treatment differences were considered significant where $P < 0.05$. Means of treatment parameters

Table 3. Annual standing biomass production of tall fescue.

Treatment	year			
	1982	1983	1984	1986
	$\mathrm{Mg\ ha^{-1}}$			
	Rock mix experiment			
Sandstone (SS)	6.3a*	6.5bc	5.7a	3.4ab
2:1 SS/SiS	6.0a	9.3a	4.1a	3.9ab
1:1 SS/SiS	6.0a	7.6b	5.2a	2.9b
1:2 SS/SiS	4.4b	6.4bc	6.3a	4.4a
Siltstone (SiS)	3.7b	5.2c	4.4a	4.2ab
	Surface amendment experiment			
Control	5.8cd	5.9c	0.9e	1.6c
Topsoil (30 cm)	5.8cd	5.2c	1.7de	2.0c
Sawdust (112 $\mathrm{Mg\ ha^{-1}}$)	3.7d	5.6c	2.8cd	2.4bc
Sludge (22 $\mathrm{Mg\ ha^{-1}}$)	3.9d	5.2c	2.7cd	2.6bc
Sludge (56 $\mathrm{Mg\ ha^{-1}}$)	7.7bc	10.1b	4.4bc	5.2ab
Sludge (112 $\mathrm{Mg\ ha^{-1}}$)	9.3ab	13.6ab	4.8b	7.2a
Sludge (224 $\mathrm{Mg\ ha^{-1}}$)	10.7a	16.5a	7.5a	5.0ab

* Column means followed by different letters by years are significantly different ($P = 0.05$).

found to be significant were separated by Fisher's protected Least Significant Difference comparison.

RESULTS AND DISCUSSION

Biomass Production

First year (1982) tall fescue standing biomass was highest (6.3 $\mathrm{Mg\ ha^{-1}}$) in the SS treatment and decreased regularly as SiS content increased in Exp. I (Table 3). Although standing biomass on the SiS treatment was again lowest in 1983 (5.2 $\mathrm{Mg\ ha^{-1}}$), the SS and 1:2 SS/SiS treatments supported similar production levels. Biomass production in 1984 and 1986 was highest on the 1:2 SS/SiS treatment. Treatments with higher SiS contents supported production in the fifth year that equaled or exceeded high SS treatments. Pedogenic changes over time and stabilization of mine soil surface properties reduced parent material affects on biomass production. Spoil type effects were most noticable in the second year of the study (1983) when maximum production occurred. The lower biomass production on high SiS spoils is attributed to initially high pH (Table 4) and to detrimental physical properties such as rockiness, low water availability, and restricted rooting volume (Roberts, 1986). Siltstone had similar effects on establishment and early growth of pines as reported by Torbert et al. (1984). Not all siltstone-derived spoils are extremely coarse and high in pH, so care must be taken in extrapolation of these results on even a regional basis. These relationships point out that spoil type has an important influence on the first 2 yr of fescue growth. Parent material effects diminish once the spoil surface is stabilized by litter layer development, organic matter accumulation, and leaching of soluble salts (Roberts, 1986).

The annual addition of 56 $\mathrm{kg\ N\ ha^{-1}}$ in the absence of legumes in Exp. I was sufficient to maintain reasonable fescue production. This annual N addition rate is less than half of the total N that a vigorous legume component would supply to the mine soil-plant system (Dancer et al., 1977). There is a large difference in immediate availability between the two N sources, but in the long term, the build-up of a potentially mineralizable pool of organic N is critical to meet the N demand of nonleguminous grasses. All plots in Exp. I maintained virtually complete ground cover for five growing seasons. Legumes were excluded from these experiments to avoid the development of differing vegetative communities across treatments, particularly in Exp. II. We speculate that overall biomass production and ground cover would have been much greater in 1984 and 1986 had a vigorous legume component been present.

Tall fescue production generally increased as the sludge amendment rate increased in Exp. II (Table 3). Treatments amended with >56 $\mathrm{Mg\ ha^{-1}}$ sludge supported about twice as much fescue growth as other treatments for all 5 yr of the study. Sawdust and 22 $\mathrm{Mg\ ha^{-1}}$ sludge treatments supported fairly constant but low yields each year of the study. Large amounts of slow release N were added to the sawdust plots initially to offset N immobilization, but did not appear to influence production during the experiment. Control and topsoil treatments

Table 4. Mine soil pH, total N, bicarbonate-extractable P, and total CEC at a depth of 0 to 5 cm in Exp. I and II in 1982, 1983, and 1984 in the <2-mm soil fraction.

Treatment	Year											
	1982				1983				1984			
	pH	Total N	Ext. P	CEC	pH	Total N	Ext. P	CEC	pH	Total N	Ext. P	CEC
		$\mathrm{mg\ kg^{-1}}$		$\mathrm{cmol_c\ kg^{-1}}$		$\mathrm{mg\ kg^{-1}}$				$\mathrm{mg\ kg^{-1}}$		
Experiment I												
Sandstone (SS)	5.5c*	--	78a	5.3c	5.0b	359c	47a	3.7b	5.3b	601c	52a	3.7d
2:1 SS/SiS	6.7b	--	75a	7.7ab	6.0b	485bc	52a	5.1a	6.0a	895b	37ab	5.8bc
1:1 SS/SiS	6.6b	--	64a	7.5b	6.2a	530b	42a	5.1a	6.2a	933b	40ab	5.6c
1:2 SS/SiS	7.2a	--	74a	9.0a	6.4a	529b	46a	5.6a	6.2a	1 152ab	37ab	6.8ab
Siltstone (SiS)	7.5a	–	74a	8.6ab	6.6a	809a	39a	5.5a	6.3a	1 220a	30b	7.1a
Experiment II												
Control	6.8c	620c	54bc	6.9e	6.1c	810de	50c	4.7f	6.0b	970cd	27c	5.1c
Topsoil (30 cm)	7.2ab	360c	36cd	7.7de	6.2bc	560e	42c	5.2ef	6.5a	590d	29c	5.3c
Sawdust (112 $\mathrm{Mg\ ha^{-1}}$)	6.1d	1 850b	24d	10.2cd	5.3d	2 140c	42c	7.9d	6.0b	1 980b	27c	7.5b
Sludge (22 $\mathrm{Mg\ ha^{-1}}$)	7.4a	1.190bc	22d	9.3de	6.4a	1 450cd	36c	6.6de	6.3ab	1 710bc	28c	6.7bc
Sludge (56 $\mathrm{Mg\ ha^{-1}}$)	7.3ab	1 990b	44cd	12.5c	6.4a	3 200b	82b	10.6c	6.3ab	2 510b	50b	8.6b
Sludge (112 $\mathrm{Mg\ ha^{-1}}$)	7.0bc	3 590a	81b	15.7b	6.4a	3 880b	120a	12.6b	6.0b	4 570a	80a	13.6a
Sludge (224 $\mathrm{Mg\ ha^{-1}}$)	7.0bc	4 210a	126a	19.6a	6.3ab	4 650a	145a	14.9a	6.2ab	4 190a	79a	13.5a

* Means followed by different letters within a column by year are significantly different, $P = 0.05$.

supported similar standing biomass levels that consistently were the lowest of all treatments. Maximum production occurred in 1983 on all treatments but topsoil. The plots received frequent summer thunderstorms over the first 3 yr, and the 1983 high production was not related to weather.

A comparison of the biomass production levels for the control and topsoil treatments (Exp. II), which received no annual N additions, with those of Exp. I, which were treated identically except for annual N additions, shows that small annual N additions dramatically influenced 1984 and 1986 production levels in all Exp. I treatments (Table 3). Much more uniform fescue stands were maintained in Exp. I, while fescue tended to clump in Exp. II treatments. By 1986 ground cover was quite sparse on the control and topsoil treatments, and below bond release standards on the sawdust and 22 Mg ha^{-1} plots.

The maintenance of a self-sustaining vegetative community on surface mined land that meets 5-yr bond requirements is directly related to mine soil properties and the ability of the species used to exploit soil water and nutrient reserves. Data for mine soil chemical properties across the two experiments demonstrate the dynamic nature of mine soils as they are weathered and rapidly transform over the first several years (Table 4). Mine soil pH and CEC levels were strongly dependent on spoil type, but differences moderated with age. Bicarbonate P levels were high in all treatments, particularly those receiving heavy sludge applications in Exp. II. Sucessful species like tall fescue must be able to tolerate these temporal changes, often by modifying surface soil conditions. Addition of large amounts of organic matter as sewage sludge aids this process and can support vigorous long-term fescue production in the complete absence of inorganic fertilization.

Fescue Nutrient Dynamics

The tall fescue tissue samples were taken in early October of each year and included all aboveground biomass. For that reason, levels of certain nutrients such as N were lower than those which would be present in samples taken specifically for nutrient sufficiency testing, which usually are taken from selected portions of the plant during a specific growth stage.

NITROGEN

There is little doubt that N is a major limiting nutrient in mine soils (Vogel, 1981; Mays and Bengston, 1978). Tall fescue particularly responds to N applications (Wilkinson and Mays, 1979). Nitrogen tissue concentrations were generally unaffected by spoil type in Exp. I (Table 5), but there was a consistent decrease in tissue N by about 2.0 g kg^{-1} between 1983 and 1984 in all treatments. This decrease was probably not a dilution effect since biomass production in 1982 and 1984 was similar and the 1984 tissue N concentrations were still lower. Total N uptake (kg ha^{-1}) by fescue grown on SS-derived soil was twice that of SiS in 1982 (Table 6). Mixed SiS and SS treatments accumulated more N than did either of the pure rock mix treatments in 1983. The amount of cumulative N uptake between 1982 and 1984 as a percentage of total N fertilization was 58, 68, 63, 57, and 43% for the SS through SiS treatments. Treatments with initially high N uptake supported reduced uptake rates in later years. Treatments with initially low N uptake rates supported higher N accumulation in later years. Soil total N increased in all treatments over the first three growing seasons (Table 4), even though total uptake dropped, indicating that N mineralization was limited as organic matter resistant to decomposition accumulated.

Table 5. Annual N, P, K, Ca, and Mg concentrations in tall fescue grown on mine soils of Exp. I.

Treatment	Nutrient concentration				
	N	P	K	Ca	Mg
	$g\ kg^{-1}$				
			1982		
Sandstone (SS)	9.9a*	2.0a	17.5b	2.9b	2.5a
2:1 SS/SiS	10.0a	2.0a	19.4a	3.2ab	2.7a
1:1 SS/SiS	10.2a	1.8a	18.1ab	3.3ab	2.7a
1:2 SS/SiS	9.0a	1.7a	16.9b	3.7a	2.8a
Siltstone (SiS)	9.0a	16.a	16.6b	3.7a	2.7a
			1983		
Sandstone	9.3a	1.7b	11.3b	3.1c	2.1b
2:1 SS/SiS	10.4a	2.0a	14.4a	3.9b	2.8a
1:1 SS/SiS	9.8a	1.8ab	12.8ab	3.9b	2.5a
1:2 SS/SiS	10.6a	2.0a	14.5a	4.4a	2.9a
Siltstone	10.4a	1.7b	12.8ab	4.4a	2.9a
			1984		
Sandstone	7.0b	1.3b	11.9a	2.8b	2.3b
2:1 SS/SiS	8.0a	1.8a	14.3a	3.2ab	2.8a
1:1 SS/SiS	8.0a	1.6a	13.0a	3.4ab	2.6a
1:2 SS/SiS	7.9a	1.6a	13.7a	3.4ab	2.8a
Siltstone	8.0a	1.3b	14.0a	3.6a	2.9a

* Means followed by different letters within columns by year are significantly different, $P = 0.05$ (Fisher's LSD).

Tissue N increased in Exp. II as the sludge rate in-

Table 6. Values for annual N, P, K, Ca, and Mg uptake by tall fescue grown on mine soils of Exp. I.

Treatment	Nutrient uptake				
	N	P	K	Ca	Mg
	$kg\ ha^{-1}$				
			1982		
Sandstone (SS)	62.1a*	12.5a	111.3a	18.5a	15.6a
2:1 SS/SiS	61.2a	11.9a	118.5a	19.0a	16.2a
1:1 SS/SiS	60.2ab	10.8ab	108.7a	19.5a	16.1a
1:2 SS/SiS	40.0bc	7.8bc	76.2b	15.5ab	12.1b
Siltstone (SiS)	33.3c	5.8c	63.5b	12.9b	9.7b
			1983		
Sandstone	60.4b	10.8bc	74.2bc	19.7c	13.9b
2:1 SS/SiS	98.1a	18.1a	133.9a	36.1a	25.7a
1:1 SS/SiS	77.5ab	14.1ab	102.8ab	29.1ab	19.8b
1:2 SS/SiS	69.1b	13.4b	94.6bc	27.5b	18.5b
Siltstone	53.8b	8.9c	66.4c	22.5bc	15.1b
			1984		
Sandstone	39.2a	7.5a	67.3a	15.9a	12.8a
2:1 SS/SiS	31.9a	7.4a	60.6a	13.2a	11.6a
1:1 SS/SiS	40.0a	8.3a	67.2a	17.3a	13.5a
1:2 SS/SiS	51.2a	10.5a	90.7a	20.8a	17.4a
Siltstone	34.6a	5.6a	60.4a	15.4a	12.7a

* Means followed by different letters within columns by year are significantly different, $P = 0.05$ (Fisher's LSD).