COMPARISON OF DIFFERENT MULCHES, LIME AND FERTILIZER APPLICATIONS ON THE ESTABLISHMENT AND GROWTH OF VEGETATION ON SURFACE COAL MINING LAND[1]

by

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Abstract. The objective of the current study was to determine the effect of different mulches, lime and fertilizer applications on the establishment and growth of vegetation on two surface mine sites in western Pennsylvania. One site was reclaimed under the current regulations (1977) while the second site was mined and reclaimed prior to the passage of PL 95-87. Experimental quadrats were established in a checkerboard manner and all but one quadrat, which served as a control, received either mulch, lime and/or fertilizer alone or in combinations of mulch, lime and/or fertilizer. Quadrats were seeded with either annual rye (Lolium multiform), winter wheat (Triticum aestivum), K-31 fescue (Fescue aurndinacea), alfalfa (Medicago sativa) or buckwheat (Fagopyrum sagittatum). Generally, those quadrats that were mulched with either straw or bark enhanced the establishment of vegetation to a greater degree than newsprint, which in some cases was detrimental, when compared to the control. However,considerable variation existed among the different species in their response to mulch and/or lime fertilizer applications. Generally the response of vegetation to all treatments was better on the site with top soil replacement than it was on the older site which was reclaimed in the early 1960's.

Additional key words: Mulch, Lime, Fertilizer, Establishment, Growth, and Biomass of Winter Wheat, Annual Rye, Fescue, Alfalfa, Buckwheat.

Introduction

The application of mulch, lime and fertilizer has been a standard practice in reclaiming mine lands for over two decades. Previous studies have shown that mulching will enhance the establishment and growth of vegetation on disturbed lands (Dyer et al. 1984). These authors found that bark was slightly superior to hay as a mulch but that no single mulch was best for all soil types. These authors further indicated that considerable variability existed in the response of vegetation to different mulches and that some mulches could have an adverse effect on vegetation. In general, the use of mulches which are high in organic matter, such as bark chips, hay and straw, were better for the establishment of legumes than for grasses. In the southwest, Elkins et al. (1983) found that bark as an organic amendment to minesoils was as effective in developing a productive soil profile as the more expensive applications of topsoil and mulch currently recommended for surface mine reclamation.

Lime and fertilizer applications prior to seeding is a common practice in re-vegetating mined lands. DePuit and Conenbert (1979) found that a light fertilizer application may be best to enhance species diversity while prolonged fertilizer applications will increase biomass production.However,fertilizer applications at maintenance levels had little long-term impact on soil fertility. In another study, Hanson et al.(1982) found that lime application increased yield for one year but not the following year and that there was not a significant difference between sites receiving lime applications and those which did not. McFee et al. (1981) found that the application of 10-10-10 fertilizer improved the growth of both wheat and alfalfa on all types of overburden except black and gray shales. It appears therefore, that lime fertilizer applications may be important for the initial establishment of vegetation but may not be important in maintaining long-term fertility and biomass production unless fertilizer application is continued on an annual basis.

Materials and Methods

Experimental $3m^2$ quadrats were established in a 4x4 checkerboard design on two mine sites (3 replicas per site) located in the glaciated plateau providence of northwestern Pennsylvania. The overburden overlaying the Brookeville coal of the Clarion Formation consisted of glacial till along with shale and sandstone directly

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above the coal seam. The glacially derived soils on both sites had a pH between 6.0 and 6.6 and the organic content between 3.0% and 4.8% with a moisture content at saturation between 15 and 22%.

The first site, hereafter referred to as site one, was mined after the passage of PL 95-87, whereas the second site, hereafter referred to as site two, was mined in the early 1960's.

All quadrats were established at the same time and were located on a level contour. A wood frame buried at a depth of 15cm separated the individual quadrats. Quadrats, which served as controls, received no treatment while the others were mulched at a rate equivalent to 3 tons/acre of either straw, bark or newsprint as mulch alone, or received various combinations of lime, fertilizer or lime and fertilizer in addition to mulching. The quadrats were limed at a rate equivalent to 2 tons/acre and 10-20-20 fertilizer applications were equivalent to 200 lb/acre as recommended by the Pennsylvania State Agronomy Guide (1987-88).

Quadrats were seeded with either annual rye (Lolium multiforum), winter wheat (Triticum aestivum), K-31 fescue (Fescue aurndinacea) and alfalfa (Medicago sativa) or buckwheat (Fagopyrum sagittatum). Winter wheat was seeded in September and all other seedlings were completed prior to 31 May. The seeding rates were based on pounds of live seeds/acre (PLS/A) as recommended in the Pennsylvania State Agronomy Guide (1987-88) for seeding on disturbed lands and establishing foliage and small grains (Table 1). All quadrats were seeded with a cyclone seeder to insure as uniform a seeding as possible.

At the end of the first growing season, the number of stems and height of all individual plants on each quadrant was determined for winter wheat, annual rye and buckwheat and the number of stems, height and the plant and root biomass/m^2 was also determined for buckwheat. After the second growing season, the biomass, chlorophyll a and plant height and root length of K-31 fescue and alfalfa was determined on each quadrat. The amount of chlorophyll a was also determined according to the procedures described by Richards and Thompson (1952), Parson and Strickland (1963), and Brenner et al. (1975). Chlorophyll a has been used as a factor in determining the importance of different species occurring on reclaimed mine lands by Brenner et al. (1975) and, thus, was used as another index of the effect of different treatments on the establishment and growth of vegetation on the different quadrats. In addition to measuring the vegetation, a soil sample was obtained from each quadrat to determine the effect of the different treatments on organic matter and moisture on pH. Since these parameters have been shown to be important in the establishment of vegetation on mined lands (Brenner et al. 1984).

Results and Discussion

Considerable variation existed among the different treatments in both soil characteristics as well as in the response of vegetation. The use of mulch had no significant effect on the amount of organic matter or the moisture content of the surface mine spoil, either among treatments or between the two mine sites as indicated by a two-way analysis of variants ($P > 0.75$).

Variation also existed among the different species of vegetation in their response to the application of the various mulches and lime-fertilizer treatments between the two mine sites. For example, with winter wheat, the number of plants per m^2 on the first mine site was greater when straw was used as a mulch than it was when quadrats were mulched with either bark or newsprint. However, on site two the number of plants/m^2 to a greater extent on site one than they did on site two. On site one, the greatest number of plants occurred when straw was used in combination with fertilizer, but there was not a significant difference in the numbers of plants/m^2 between the use of fertilizer and the use of lime-fertilizer ($P > 0.50$). However, when bark was used as a mulch, the number of plants/m^2 was greater when lime-fertilier was used, but there was not a significant difference ($P > 0.50$) between no lime fertilizer application and when

Table 1. Seeding rates of five different species on two surface coal mines in Pennsylvania receiving different treatments of mulch and lime and fertilizer applications.

SPECIES	SEEDING RATES - PLS (LB/A)
Annual Rye (Lolium multiforum)	40
Winter Wheat (Triticum aestivum)	60
K-31 Fescue (Fescue aurndinacea)	20
Alfalfa (Medicago sativa)	20
Buckwheat (Fagopyrum sagittatum)	60

fertilizer was used (Table 2). On site two except for newsprint, the number of plants/m^2 was greater on the control quadrat and on those receiving mulch than it was among the different lime and fertilizer treatments.

In contrast to winter wheat annual rye had a better response at site two to all treatment categories with the possible exception of when newsprint was used as a mulch. On site two, the greatest number of plants/m^2 occurred when no treatment was used. The greatest number of plants/m^2 among different treatments occurred when either straw or bark was used as a mulch in combination with lime (Table 2). When both lime and fertilizer or fertilizer alone was used, the number of plants/m^2 increased when straw was used as a mulch, but not on quadrats mulched with bark or newsprint. On one site, the number of plants/m^2 were greater when straw was used as a mulch in combination with lime and fertilizer, with the exception of the control quadrats or when newsprint was used as a mulch. On quadrats mulched with straw or bark, the number of plants/m^2 varied among the different treatments.

On mine site one, the use of straw along with the combinations of lime and fertilizer increased the growth of both winter wheat and rye compared to the control quadrats. But when bark was used as a mulch, winter wheat showed a greater growth response than annual rye. On site two, the use of straw with the addition of either lime or fertilizer resulted in a greater increase in the plant growth than when bark was used as a mulch. The least amount of growth on both sites occurred on quadrats mulched with newsprint, regardless of whether fertilizer or lime were applied to the site (Table 2).

K-31 fescue exhibited considerable variation among the different treatments both within and between the two mine sites. On site one, the greatest root biomass occurred on quadrats which were not mulched but received applications of lime and fertilizer, while the greatest above-ground biomass with the smallest root biomass occurred when the quadrats receiving straw along (Table 3). There was considerable variation in the height and biomass of vegetation among the other mulches as well as between treatments with lime and fertilizer (Table 3). The tallest plants occurred on quadrats mulched with newsprint in conjunction with lime, but considerable variation occurred among the other treatments. On site two, the greatest above-ground biomass occurred when bark alone was used as mulch, but the greatest root biomass occurred when bark was used in conjunction with lime and fertilizer. Overall, there was no significant difference in the

Table 2. The number of stems/m^2 and height of winter wheat (*Triticum aestivum*) and annual rye (*Lolium multiforum*) on quadrats receiving different mulch, lime and fertilizer applications.

	Number/m^2				Height mm			
	Winter Wheat		Annual Rye		Winter Wheat		Annual Rye	
	Site				Site			
Treatment	1	2	1	2	1	2	1	2
No mulch	130	48	49	116	618	482	522	505
Lime	98	10	48	55	522	313	499	513
Fertilizer	53	8	24	42	261	250	485	324
Lime-Fertilizer	50	21	30	53	315	478	491	345
Straw	153	49	28	54	989	511	788	498
Lime	178	8	47	80	1012	486	791	987
Fertilizer	235	9	53	46	1058	361	496	965
Lime-Fertilizer	235	5	58	62	1062	483	601	503
Bark	105	78	25	47	510	281	302	266
Lime	153	11	48	77	768	260	328	278
Fertilizer	102	3	52	25	518	272	343	485
Lime-Fertilizer	155	1	54	48	783	291	331	472
Newsprint	53	3	2	8	260	262	452	183
Lime	52	3	3	28	260	105	448	101
Fertilizer	25	1	15	8	125	245	435	114
Lime-Fertilizer	50	3	4	12	266	251	410	256

height and among the biomass of vegetation different mulches or lime and fertilizer applications a indicated by a two-way analysis of variance ($P > 0.50$).

As with K-31 fescue, alfalfa also showed a considerable variation among the different treatment but there was not as great a difference between the two sites as occurred with K-31 fescue or winter wheat and annual rye. In terms of biomass, site one had a slightly greater biomass per m^2 among the different treatments than site two (Table 4). Overall, on site one quadrats with mulch had a greater biomass/m^2 than the control quadrats, with the possible exception of the control quadrats that received lime and fertilizer applications but differences occurred in the amount of above-ground and root biomass on site one among the different treatments (Table 4). On site two plant and root length, was greatest on the quadrats that received bark mulch without lime and fertilizer and there was not a significant difference among the other treatments in either the plant height or root length. Also on site two, the greatest biomass occurred on the control quadrats receiving the lime applications (Table 4). Generally the plants obtained their greatest height and bioma s/m^2 when bark and newsprint were used as a mulch rather than straw.

As with biomass/m^2 and plant height, the mg chlorophyll a kg varied among the different treatments on the two sites. In general, among the different treatments the chlorophyll a/kg was greater in fescue than it was in alfalfa. On site one, the greatest concentrations of chlorophyll a occurred in fescue on the quadrats mulched with bark or newsprint along with receiving lime and fertilizer application ($P > 0.50$). As with site one, the greatest concentration of chlorophyll a occurred in plants on the control quadrat receiving lime and fertilizer applications (Table 3,4).

The number of buckwheat plants/m^2 on both sites tended to be greater on quadrats mulched with straw or bark than it was on the control quadrat or those mulched with newsprint (Table 5). In regards to the effects of lime and fertilizer treatments on the number of plants/m^2 were significantly greater on quadrats receiving straw along or straw and lime that it was on the other quadrats ($P > 0.05$). However, there was not a significant difference in the number of plants/m^2 on the quadrats mulched with straw and those mulched with straw along with applications of lime and fertilizer ($P > 0.50$). When bark was used as a mulch, the number of plants/m^2 was essentially the same between the quadrats receiving fertilizer applications and those receiving no additional treatments. On site two, quadrats receiving straw and bark with no addition of lime and fertilizer had a greater number of plants/m^2 than those receiving various combinations of lime and fertilizer. Generally, the number of plants/m^2 on those plots mulched with newsprint did not differ significantly from the control quadrats ($P > 0.50$).

On site one, the greatest total biomass of buckwheat occurred on quadrats mulched with straw or bark in combination with either lime or fertilizer. While on site two, the greatest total bio-

Table 3. Height, Biomass, Dry Weight and Chlorophyll a concentration of K-31 fescue (Festucue aurndinacea) grown on quadrat receiving different mulch, lime and fertilizer applications.

	Length mm				Biomass g/m^2				Chlor. a	
	Plant Site		Root Site		Plant Site		Root Site		mg/kg Site	
Treatment	1	2	1	2	1	2	1	2	1	2
No mulch	70	145	50	85	10.5	12.7	2.5	4.8	23	28
Lime	61	97	99	8	8.3	8.7	3.0	1.5	27	27
Fertilizer	135	148	65	50	6.0	20.2	4.5	2.3	23	49
Lime-Fertilizer	100	168	90	25	9.7	14.8	19.8	3.2	24	48
Straw	100	95	50	98	29.0	18.0	2.0	5.0	48	74
Lime	97	70	53	53	9.8	17.8	8.0	10.1	26	49
Fertilizer	80	135	30	12	6.7	13.9	3.8	3.1	49	73
Lime-Fertilizer	79	105	31	98	17.0	15.8	7.5	4.7	53	72
Bark	117	152	63	47	10.3	35.1	2.2	9.7	26	77
Lime	149	186	51	9	5.7	18.0	5.8	3.8	75	50
Fertilizer	183	205	15	15	1.8	9.3	2.0	1.2	23	49
Lime-Fertilizer	135	120	75	98	6.8	33.5	3.1	17.5	27	75
Newsprint	80	120	40	30	8.2	14.8	1.5	2.2	10	49
Lime	125	144	75	52	5.4	12.5	4.5	5.6	12	47
Fertilizer	135	169	75	51	3.8	2.7	1.8	2.1	53	77
Lime-Fertilizer	147	159	73	51	3.3	17.0	1.7	2.2	25	76

Table 4. Height, biomass, dry weight and chlorophyll a concentration of alfalfa (Medicago sativa) grown on quadrats receiving different mulch, lime and fertilizer applications.

	Length mm				Biomass g/m^2				Chlor. a	
	Plant Site		Root Site		Plant Site		Root Site		mg/kg Site	
Treatment	1	2	1	2	1	2	1	2	1	2
No mulch	244	180	201	155	16.5	10.6	11.0	15.0	26	26
Lime	284	290	155	185	12.4	18.9	8.1	30.2	24	25
Fertilizer	256	136	199	50	9.7	7.8	10.5	2.2	26	27
Lime-Fertilizer	205	140	210	110	26.9	15.0	19.9	10.0	50	50
Straw	170	108	180	180	20.7	13.8	16.1	15.7	26	27
Lime	135	107	175	178	20.1	14.2	12.7	16.3	13	11
Fertilizer	225	187	174	100	18.6	29.0	17.9	10.0	14	24
Lime-Fertilizer	223	143	176	156	21.6	19.4	18.2	16.3	27	26
Bark	305	192	230	188	29.5	16.5	22.5	19.7	23	24
Lime	240	295	205	105	21.4	29.1	19.8	10.8	22	23
Fertilizer	320	269	135	130	28.3	17.8	11.5	11.2	15	13
Lime-Fertilizer	253	245	145	165	30.1	20.0	11.7	21.0	25	25
Newsprint	278	285	120	120	22.4	22.6	16.8	15.0	12	23
Lime	288	175	110	157	34.0	16.5	17.2	16.3	13	24
Fertilizer	210	237	113	158	15.9	21.6	16.1	16.4	27	27
Lime-Fertilizer	335	210	110	200	24.6	20.0	17.4	19.9	25	24

Table 5. Number of stmes/m, height and biomass and dry weight of buckwheat (Fagopyrum sagittatum) grown on quadrats receiving different mulch, lime and lime and fertilizer applications.

	Number of stems/m^2		Length mm				Biomass g/m^2			
	Site		Plant Site		Root Site		Plant Site		Root Site	
Treatment	1	2	1	2	1	2	1	2	1	2
No mulch	77	61	345	260	35	15	5.0	93.5	17.0	16.5
Lime	78	60	352	259	28	17	79.0	47.0	22.0	16.8
Fertilizer	101	62	453	282	35	18	103.0	146.5	22.0	22.4
Lime-Fertilizer	49	59	380	580	25	50	82.5	85.9	16.0	15.2
Straw	155	105	263	390	25	15	21.5	39.8	22.0	15.8
Lime	161	75	367	372	28	13	99.4	32.8	101.1	16.0
Fertilizer	248	78	377	499	28	16	200.9	115.8	21.9	22.7
Lime-Fertilizer	53	79	371	589	24	10	22.7	170.3	16.1	10.0
Bark	125	140	227	271	18	14	14.0	110.5	8.5	8.9
Lime	75	76	350	387	28	15	189.4	178.8	100.5	22.0
Fertilizer	126	80	370	563	29	15	160.8	178.7	135.0	22.1
Lime-Fertilizer	52	85	403	627	12	18	18.0		17.0	19.8
Newsprint	54	48	194	286	11	14	6.0	80.9	16.0	18.9
Lime	51	51	383	599	35	16	7.5	178.7	16.2	20.1
Fertilizer	20	52	451	573	34	17	7.3	254.1	15.0	45.8
Lime-Fertilizer	78	55	374	520	36	85	6.7	267.9	15.3	22.1

mass of buckwheat occurred when bark alone was used as a treatment followed by quadrats mulched with bark along with lime and fertilizer. Overall, on site one, there was not a significant difference among the various treatments ($P > 0.50$). However, those quadrats receiving mulch and/or lime-fertilizer applications tended to have a greater biomass/m^2 than those that received only mulch (Table 5). On site two, the tendency was for the greatest biomass/m^2 to occur on those quadrats mulched with newsprint. The tallest plants occurred on quadrats receiving lime and fertilizer applications but differences occurred among quadrats receiving different treatments.

As in previous studies, considerable variation existed in the response of the vegetation to the various treatments. Overall, traw and bark appeared to stimulate both the establishment and growth of vegetation on surface mine lands but the response varied among the different species. Likewise, the addition of lime and fertilizer either with or without the use of mulch tended to enhance the establishment and growth of vegetation, but variations also occurred with all species tested. In some instances, the growth was equal to or greater on the control plots which did not receive any additional treatment. In general, with all species tested, the response of vegetation among the various treatments was greater on site one which was reclaimed in accordance with the PL 95-87 regulations as to the placement of top soil than it was on the older mine site which was mined in the early 1960's.

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