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LIME HELPS ESTABLISH CROWNVETCH ON COAL-BREAKER REFUSE

by Miroslaw M. Czapowskyj and Edward A. Sowa

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NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082

The Authors

MIROSLAW M. CZAPOWSKYJ, a native of Ukraine and a United States citizen since 1957, received a Diplomforstwirt degree from Ludwig-Maximilians University, Munich, Germany, in 1949. He obtained an M.S. degree in forestry from the University of Maine in 1958 and a Ph.D. degree in soils from Rutgers University in 1962. He joined the Northeastern Forest Experiment Station in 1961 as a research forester and was assigned to the strip-mine reclamation project at Kingston, Pa., for 11 years. In 1973 he was transferred to the Station's project in culture of northeastern conifers with emphasis on spruce and fir, at Orono, Maine.

EDWARD A. SOWA is a forestry technician at the Station's research unit at Kingston, Pa. He has been located there since 1954, where he has served in research projects in forest management, watershed, wildlife habitat, and forest recreation. He is presently assigned to the surface mining restoration project. He holds an AD in science.

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ABSTRACT

A study was begun in 1965 to determine the effect of lime, fertilizer, and mulch on the establishment and growth of crownvetch crowns planted on anthracite coal-breaker refuse. After 7 years the lime application had by far the strongest effect. Both 2.5 and 5.0 tons per acre increased survival and ground cover manyfold, and both treatments were equally beneficial from the first to the seventh growing season. The benefits of fertilizer and mulch were much less. Lime raised the pH to the neutral range, and this range was still the same 7 years after treatment. Exchangeable Ca and Mg were raised, and percentage of base saturation and cation exchange capacity increased significantly on areas that received lime and fertilizer treatments.

Keywords: coal-breaker refuse, crownvetch, spoil amendments.

IN MORE THAN 30 YEARS of experience with test plantings in the Anthracite Region of Pennsylvania, few plantings have succeeded on coal-breaker refuse. Now we have recent evidence that coal-breaker refuse will support vegetation if the refuse is adequately limed, fertilized, and mulched.

In a study begun in 1965, we learned that Penngift crownvetch *(Coronilla varia L.)* could be established on coal-breaker refuse by planting crowns and using lime, fertilizer, and mulch treatments; and that, when established, the crownvetch provided quick and effective cover *(Czapowskyj and others 1968; Czapowskyj and Sowa 1973)*.

In the work reported here, our objective was to determine how long effects of lime and fertilizer last. We did this by (1) estimating changes in ground cover of crownvetch during the 7-year period after establishment, (2) comparing pH of the treated refuse immediately after treatment, and (3) comparing chemical characteristics of untreated refuse with those of treated refuse 7 years after treatment.

THE STUDY

The study was established in 1965 in the vicinity of Tamaqua, Pennsylvania, on lands leased by the Greenwood Stripping Company. The site and study design have been briefly described in previous reports.

Site.—The experimental site we selected was on the plateau top of a coal-breaker refuse pile. The refuse consists of fragmented carbonaceous rocks associated with coal seams but separated from coal in a cleaning plant — a breaker. The site was practically level and somewhat compacted by truck traffic. It was bare of vegetation.

An analysis showed that the refuse consisted 75 percent of shale fragments and coal pieces larger than 2 mm and 25 percent of material smaller than 2 mm. Bulk density was 1.6 gm/ccm, and total porosity was 14 percent. The material retained 1.0 inch of available water per foot depth (2.4 cm per 30 cm). Acidity ranged from pH 3.7 to 4.0.

STUDY DESIGN AND ESTABLISHMENT

We had six 30x60-foot blocks, three each for the 1965 and 1966 plantings. Each block was divided into three plots for lime treatments; and each of these was subdivided into three subplots for fertilizer treatments. The subplots were split in two for mulch treatments. Thus the ultimate units were 10 by 10 feet. Lime and fertilizer treatments were assigned randomly, but adjacent plots were used for mulch treatment to minimize the problem of holding the mulch in place.

The treatments consisted of all combinations of three levels of hydrated lime (125 percent calcium carbonate equivalent), three levels of 5-10-5 fertilizer, and two levels of straw mulch, as follows:

Lime: 0, 2.5, and 5.0 tons per acre.
Fertilizer: 0, 250, and 500 pounds per acre.
Mulch: 0 and 1 bale of about 50 pounds of straw per block.

The liming rates were based on lime-neutralization tests. The 2.5- and 5.0-ton rates were calculated to raise the pH to about 6.0 and 6.5 respectively. Rates for fertilizer and mulch represented arbitrary judgments of reasonable amounts.

Lime and fertilizer were applied with a calibrated seed and fertilizer spreader shortly after the spring thaw. The mulch was spread by hand after planting.

In spring 1965, 25 two-year-old crownvetch crowns, each including 8 to 10 inches of taproot, were hand-planted with mattock at 2x2-foot spacing in 3 of the blocks. Each block thus contained 450 crowns, and the entire planting in 1965 totaled 1,350 crowns.

In spring 1966, the other 3 blocks were planted the same way as described above. This resulted in 6 blocks planted with a total of 2,700 crowns.

MEASUREMENTS AND ANALYSIS

Crownvetch

We measured both the survival and ground cover for the first three growing seasons. Ground cover was determined by measuring the diameter of each plant in three directions and computing an average diameter. The ground-cover area of the plants was later calculated and converted to a percentage of the sub-subplot area. In the analysis of variance the survival rates and percentage of ground cover were transformed into arcsine values.

After 3 years the survival had leveled off, and the ground cover had increased by runners so it was difficult to recognize individual plants. Therefore we measured only the ground cover in later years. Ground cover was obtained by averaging visual estimates of three workers.

Breaker Refuse

Seven years after treatments, we collected refuse samples from the 0 to 6-inch surface layer and the 6 to 12-inch layer. The samples were air-dried and passed through a 2-mm sieve. The material less than 2 mm diameter was subjected to the following chemical analyses:

1. pH values were determined, using an electronic pH meter on 1 to 1 refuse: water ratio samples.

2. Exchange acidity was determined according to the method outlined by Adams and Evans *(1962)*; available cations were extracted with neutral 1N NH_4OAc and determined by atomic absorption, phosphorus was extracted as suggested by Nelson and others *(1953)* and was determined colorimetrically.

Table 1.—Percentage survival of crownvetch planted on anthracite coal-breaker refuse

[Average of three replications]

Growing season	Fertilizer applied	Lime applied at rate (tons/acre) of—					
		0		2.5		5.0	
		No mulch	Straw mulch	No mulch	Straw mulch	No mulch	Straw mulch
	Pounds/acre	*Percent*					
		PLANTED IN 1965					
1	0	15	21	89	95	92	97
2	0	0	8	79	88	87	92
3	0	0	1	75	88	83	92
1	250	11	15	83	95	84	93
2	250	1	8	79	89	80	80
3	250	0	4	72	87	79	80
1	500	5	11	89	92	85	88
2	500	1	1	84	92	79	88
3	500	0	0	81	92	79	88
		PLANTED IN 1966					
1	0	8	1	48	55	65	67
2	0	1	1	41	55	57	67
3	0	0	1	41	55	57	67
1	250	3	0	60	53	56	52
2	250	0	0	49	52	44	51
3	250	0	0	49	52	44	51
1	500	3	2	55	68	74	74
2	500	0	2	54	68	74	74
3	500	0	2	54	68	74	74

RESULTS AND DISCUSSION

Lime, fertilizer, and mulch produced a difference in crownvetch performance and in chemical characteristics of the breaker refuse.

Crownvetch

Lime was the most important factor in survival and growth of crownvetch (tables 1, 2, and 3). Lime increased survival and ground cover manyfold. The rates of lime at 2.5 and 5.0 tons were equally beneficial from the first through the third growing seasons. The strong response to lime was what we expected, because crownvetch requires a relatively high pH and high available calcium for best growth.

From the nearly equal responses to the 2.5- and 5.0-ton-per-acre applications of

Table 2.—Percentage of ground cover produced by crownvetch planted on anthracite coal-breaker refuse

Growing season	Fertilizer (lbs./acre)	Lime applied at rate (tons/acre) of—					
		0		2.5		5.0	
		No mulch	Straw mulch	No mulch	Straw mulch	No mulch	Straw mulch
		PLANTED IN 1965					
1	0	<1	<1	4	10	6	8
2		0	<1	5	8	4	9
3		0	0	10	20	13	19
4*		—	—	—	—	—	—
5		0	0	55	65	55	70
6		0	0	75	80	75	85
7		0	0	80	85	80	85
1	250	<1	<1	5	17	7	13
2		0	<1	5	13	7	10
3		0	<1	12	27	14	20
4*		—	—	—	—	—	—
5		0	0	55	80	60	65
6		0	0	80	95	80	90
7		0	0	85	95	80	90
1	500	<1	<1	7	12	6	12
2		<1	0	6	10	5	11
3		0	0	15	25	15	23
4*		—	—	—	—	—	—
5		0	0	70	75	70	70
6		0	0	80	90	90	90
7		0	0	90	90	90	90
		PLANTED IN 1966					
1	0	<1	<1	2	3	2	3
2		<1	<1	6	11	7	13
3		0	<1	21	34	25	32
4		0	0	45	70	50	70
5		0	0	75	90	70	80
6		0	0	80	90	85	85
1	250	<1	0	1	2	1	2
2		0	0	6	9	5	9
3		0	0	28	31	20	28
4		0	0	50	55	35	55
5		0	0	80	80	65	80
6		0	0	80	85	80	85
1	500	0	<1	2	3	2	3
2		0	<1	11	16	11	17
3		0	<1	43	48	48	51
4		0	0	70	75	70	75
5		0	0	85	80	80	85
6		0	0	90	90	90	90

*No measurements taken.

Table 3.—Significance levels of hypothesis tested in analyses of variance

Source of variation	Survival, by growing season		Ground cover, by growing season	
	First	Third	First	Third
Year planted (Y)	**	**	**	**
Lime (L)	**	**	**	**
Mulch (M)	*	N.S.	**	*
Fertilizer (F)	N.S.	N.S.	*	**
Y x L	**	**	**	**
L x M	N.S.	N.S.	*	N.S.
M x F	N.S.	N.S.	**	**

*=Significant at 5-percent level.
**=Significant at 1-percent level.
N.S.=Not significant.

lime, we infer that the smaller amount was ample. It is possible that less than 2.5 tons per acre may be adequate.

The responses depended on the year of planting. The analyses revealed that the plots planted in 1965 had significantly (1-percent level) higher average survival and percentage of ground cover than those planted in 1966. This was probably because the 1966 growing season was especially dry. However, the effect of planting year was the opposite after the third growing season. The 1966 planting had lower survival (table 1) but better ground cover than the 1965 planting (table 1 and 2).

Furthermore, the analyses showed highly significant effects of both survival and ground-cover percentages due to lime application and planting-year interactions. The analysis showed that this difference was due primarily to the lime alone, because there was practically no survival nor ground cover on unlimed sites — for both planting years.

The fertilizer treatments did not affect the survival of crownvetch. However, added fertilizer did produce more ground cover. These effects were statistically significant at the 5-percent level during the first growing season for planting year 1965. By the third growing season, the effects were highly significant (1-percent level), even though there were some inconsistencies. The favorable response was due mainly to the pronounced increase in ground cover for the 1966 planting. The analysis showed that plots treated with 250 pounds per acre of fertilizer had nearly the same ground cover as the unfertilized plots. The ground cover was considerably higher during the first as well as the third growing season on the plots treated with 500 pounds per acre of fertilizer.

Mulching helped in establishing crownvetch. Mulched plots had 10 percent better survival than unmulched plots in the first growing season in the 1965 planting, and the mulched plots had almost twice as much ground cover as unmulched plots in the first growing season. In the third growing season the differences diminished.

The year and fertilizer interaction effects were examined also. The analyses showed that the percentage cover increases were due to the higher fertilizer application.

Lime and mulch interaction was significant for the ground-cover percentage for the first growing season only. The interaction was due to the lime, because the ground cover was practically zero in both mulched and unmulched plots where lime was not applied.

No significant effects of lime and fertilizer interactions were revealed.

There were practically no differences in crownvetch ground cover between the two levels of lime and two levels of fertilizer after the sixth and seventh years. Percentage of ground cover ranged from 80 to 95 percent, and a recent inspection of the planting site showed that a few subplots were completely covered with vegetation.

Coal-Breaker Refuse

Data on chemical characteristics of coal-breaker refuse 7 years after lime and fertilizer applications are presented in tables 4 and 5. The average values for pH, P, Ca, Mg, cation exchange capacity, and base saturation (table 4) were consistently different for the surface layer (0-6 inch) as compared to those of the subsurface (6-12 inch) layer in most treatments. K and Na did not vary among the treatments.

On the unlimed plots, values for Ca and Mg were consistently higher in the subsurface layer, especially where fertilizer was added. The P values were somewhat higher in the surface layer. On limed plots all values except Mg, K, and Na were consistently and markedly higher in the surface layer. The value for the subsurface layer also increased as compared to that of unlimed plots, indicating that some leaching occurred.

The values for exchangeable micronutrients Mn, Cu, Zn, and Fe are given in table 5. None of these seemed to be in quantities toxic to the plant; and the treatments affected the level only slightly, with the exception of Zn, which was somewhat higher.

Lime had the stronger direct effect on improvement of coal-breaker refuse fertility. Both 2.5- and 5.0-ton-per-acre applications increased the pH values, exchangeable Ca, cation exchange capacity, and percentage of base saturation of the surface layer to satisfactory levels. The Ca values were higher on plots with 5.0 tons per acre as compared to those with only 2.5 tons. The values for P increased only slightly.

The effects of commercial fertilizer were neither of great magnitude nor consistent; perhaps the application of higher rates would have produced more effect.

The biological effects also have to be mentioned. All the crownvetch died on unlimed plots. Crownvetch covered 80 to 95 percent of the ground on limed plots. The crownvetch produced a vigorous vegetative cover above the ground and an extensive root system in the surface layer. Thus the plants themselves contributed to site fertility. The

Table 4.—Selected chemico-nutritional characteristics of anthracite coal-breaker refuse 7 years after lime and fertilizer application

Applications per acre			pH	Extractable P	Exchangeable bases							Base saturation
Lime	Fertilizer	Depth			C.E.C.	Ca++	Mg++	K+	Na+	Total	Exchange acidity	
Tons	*Lbs.*	*In.*	*pH*	*ppm*	*me/100 gm of soil*							*Pct.*
0	0	0-6	3.8	1.0	3.0	0.1	0.1	0.1	0.1	0.4	2.6	13
		6-12	3.9	.7	3.1	.4	.2	.1	.1	.8	2.3	26
	250	6-0	4.0	1.2	3.3	.3	.2	.1	.1	.1	2.6	21
		6-12	4.1	.7	2.9	.6	.4	.1	.1	1.2	1.7	41
	500	0-6	4.0	1.6	3.2	.2	.2	.1	.1	.6	2.6	19
		6-12	4.0	1.0	3.5	.5	.8	.1	.1	1.5	2.0	43
2.5	0	0-6	6.6	1.4	6.5	5.9	.2	.1	.1	6.3	.2	97
		6-12	4.6	.5	3.6	1.7	.3	.1	.1	2.2	1.4	61
	250	0-6	5-1	1.5	4.5	3.2	.2	.1	.1	3.6	.9	80
		6-12	4.0	.8	3.5	1.4	.2	.1	.1	1.8	1.7	51
	500	0-6	5.6	2.4	4.2	3.2	.2	.1	.1	3.6	.6	86
		6-12	4.2	1.4	2.9	1.0	.2	.1	.1	1.4	1.5	48
5.0	0	0-6	7.1	1.6	8.0	7.5	.2	.1	.1	7.9	.1	99
		6-12	5.0	1.2	3.2	2.4	.2	.1	.1	2.8	.4	88
	250	0-6	7.3	1.0	9.6	9.0	.3	.1	.1	9.5	.1	99
		6-12	4.9	1.0	3.7	2.6	.2	.1	.1	3.0	.7	81
	500	0-6	6.6	1.2	6.9	6.4	.3	.1	.1	6.9	.0	100
		6-12	4.7	.7	3.9	2.9	.3	.1	.1	3.4	.5	87

Table 5.—Amount of micronutrients present in anthracite coal-breaker refuse 7 years after lime and fertilizer application

Applications per acre			Exchangeable —			
Lime	Fertilizer	Depth	Mn	Cu	Zn	Fe
Tons	*Lbs.*	*In.*	- - - - - - - - *ppm* - - - - - - - -			
0	0	0-6	0.25	0.37	2.67	1.25
		6-12	.75	.25	1.93	1.50
	250	0-6	.62	.25	1.25	2.00
		6-12	1.00	.25	1.73	1.75
	500	0-6	.37	.37	1.39	1.25
		6-12	.88	.25	1.36	2.00
2.5	0	0-6	.37	.62	3.30	.75
		6-12	.88	.63	1.90	.50
	250	0-6	.50	.25	3.09	.75
		6-12	.75	.38	2.05	.50
	500	0-6	.50	.50	2.30	.25
		6-12	.75	.50	1.99	1.00
5.0	0	0-6	.50	.37	2.85	1.50
		6-12	.50	.50	4.06	1.00
	250	0-6	.37	.62	4.35	1.25
		6-12	.50	.62	3.98	1.50
	500	0-6	.13	.50	4.35	.50
		6-12	<.10	.50	3.86	1.00

increases in cation exchange capacity on limed plots may be attributed, in part, to an increase of organic material produced by the crownvetch as well as the direct effect of increased pH on cation exchange capacity.

CONCLUSIONS

The 7-year results from this study permit the following conclusions:

- Lime is essential for establishment and growth of crownvetch on highly acid anthracite coal-breaker refuse.
- The lower liming rate—2.5 tons per acre—was as beneficial as the higher rate—5.0 tons per acre.
- Effects of lime were evident in neutralizing acidity, increasing availability of Ca, cation exchange capacity, and base saturation of the coal-breaker refuse.
- Lime effects in establishing crownvetch, neutralizing acidity, and improving fertility were still strongly in evidence 7 years after treatment.
- The low rates of fertilizer had little influence upon survival but enhanced the establishment of ground cover.
- Mulch provided some benefit in establishing ground cover.

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