Wheat Establishment for Mulch on Coal Mine Soil in a Semiarid Environment[1]

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Abstract
Experiments were conducted on the Black Mesa Coal Mine near Kayenta, Arizona over a 2-year period (1977 and 1978) to study the germination (emergence), seedling establishment, and ground cover from wheat (*Triticum aestivum* L.) in undisturbed soil and coal mine soil (spoils). Growth of wheat was evaluated for two fertilizer treatments applied at the rates of 0 kg/ha and 560 kg/ha of ammonium phosphate and two soil moisture treatments (optimum and insufficient). The coal mine soil was leveled to conform to the surrounding rolling topography. In April of each year wheat was broadcast planted due to the rough terrain, fertilized at planting time, and irrigated as needed (using wheat plants as indicators of moisture stress). Seeds germinated per unit area, seedlings established per unit area, and percent ground cover were recorded. These three parameters were higher in undisturbed soil than in coal mine soil, when fertilized than when not fertilized, and when optimum soil moisture was provided than when seeds were stressed for moisture. At the end of the growing season, the wheat straw was incorporated into the soil surface and was used as a mulching material. In coal mine wastes in a semiarid environment, the area must be fertilized and provided with optimum soil moisture to produce the maximum growth of wheat for immediate ground cover and soil mulch. *Additional Index Words:* Mine Spoils, Revegetation, Stabilization, Disturbed Land, Environmental Pollution.

Introduction
The removal of earth, rock, and overburden materials in the recovery of underground minerals disturbs many hectares annually. Reclamation research has shown that it is possible to grow different introduced plant species on mine wastes. Mines located in semiarid and arid environments are particularly difficult to revegetate due to limited soil moisture.

Revegetation with perennial plant species has been most successful when organic matter was incorporated into the soil surface. Straw from cereal grains can be incorporated into the soil surface to create a more desirable soil medium into which adapted, perennial plant species can be established.

The objectives of this experiment were to study germination (emergence), seedling establishment, and ground cover from wheat (*Triticum aestivum* L.) grown for soil mulch on undistrubed soil and coal mine soil (spoils) in a semiarid environment.

Literature Review
Mine wastes occupy large areas of land that may be useful to man once they have been stabilized (Day et al., 1976). The establishment of vegetation on newly-graded mine waste slopes is the most economical method of controlling erosion and providing stabilization (Day and Ludeke, 1978). Re-

Table 1. Values for pH, EC_e + 10^3, ESP, total soluble salts, nitrogen (N), phosphorus (P), potassium (K), sodium (Na), and organic matter (OM) in unmined soil and coal mine soil from the Black Mesa Coal Mine, Kayenta, Arizona for the field study initiated in 1977.

Soil material	pH	$EC_e \times 10^3$	ESP	Total soluble salts (ppm)	N (ppm)	P (ppm)	K (ppm)	Na (ppm)	OM (%)
Unmined soil	7.4	2	0	1190	6.0	2.3	18	46	1.2
Coal mine soil	6.6	6	1	4270	78.0	0.5	38	208	3.4

Note: N, K, and Na were obtained by water soluble extraction and P was obtained by CO_2 extraction.

vegetation studies indicated that some types of overburden support vegetation as well as existing undisturbed soil materials (Payne, 1978).

Plass (1978) found that annuals can be used as a temporary cover to protect a site until perennials are established. Jones et al. (1975) utilized a two-step system for revegetation of surface mine spoils in which a fast-growing initial ground cover was planted to minimize erosion and then that cover was chemically killed for use as an on-site mulch. Broadcast seeding produced a more desirable surface for retaining precipitation, controlling water pollution, and establishing a more uniform plant distribution (Day and Ludeke, 1973). Species that spread vegetatively were most efficient for soil stabilization (Argall, 1975). Power et al. (1978) found that introduced species were easier to establish and were more tolerant to adverse environmental conditions but they required more soil preparation for effective establishment.

Soils should be conditioned with organic matter to improve soil structure and increase resistance to surface crusting (Luellen, 1977). Bennett (1977) stated that forages provided an economical, quick ground cover and aided in the restoration of spoils material to a productive soil. Ludeke et al. (1974) found that it was necessary to incorporate straw or other forms of organic material into the surface of copper tailings slopes to obtain satisfactory plant growth. Day et al. (1976) suggested that forage for livestock grazing may be produced by growing spring barley (*Hordeum vulgare* L.) on copper mining wastes in Arizona.

Day et al. (1979) stated that when adapted plant species were grown under optimum conditions, coal mine soil produced the same vegetation yields from alfalfa (*Medicago sativa* L.), barley, and wheat as Gila loam soil. Supplemental irrigation was needed on areas receiving less than 20 cm of precipitation annually (Aldon, 1978).

Materials and Methods

Germination (emergence), seedling establishment, and ground cover from Super X spring wheat were studied in experiments conducted on undisturbed soil and coal mine soil (spoils) with two fertilizer and two soil-moisture treatments on the Black Mesa Coal Mine, Kayenta, Arizona over a 2-year period (1977 and 1978).

The Black Mesa is located in northeastern Arizona at an elevation of about 2,132 m (7,000 ft.). Temperatures reach extremes of from −20 C to 35 C. The annual precipitation is about 25 cm (10 inches) and approximately one-half falls during the winter months as snow. Snowmelt occurs in late-winter and produces some runoff on unmined areas but very little runoff on mined areas. Most of the rainfall occurs as convection storms of short duration and high intensity during mid- and late-summer. These storms are spotty and occasionally result in flash floods. Dry, windy weather usually prevails from April through July and results in frequent dust storms on mined areas. The dominant vegetation on the Black Mesa is a combination of pinyon pine (*Pinus edulis* Engelm.) and juniper (*Juniperus monosperma* (Engelm.) Sarg.). The coal mine soil consists of a porous soil material that remains following strip-mining coal. The soil material occurs from a few meters to several meters in depth, in a rolling topography. The texture resembles that of a clay loam soil, however, it has very little structure. Most of the surface area may be cultivated and seeded to plant species with modified commercial agricultural equipment. The undisturbed soil on the Black Mesa has been classified as a miscellaneous land type with a variety of soil textures.

The undisturbed soil has a rolling topography with various slopes. In 1977, the coal mine soil was leveled with a bulldozer to conform to the surrounding topography. Seed beds were prepared by disking both undisturbed soil and coal mine soil with a double disk harrow. Fifty soil samples were taken at random from the surface 15 cm of each soil material. The samples were composited and analyzed for pH, $EC_e \times 10^3$, exchangeable sodium percentage (ESP), total soluble salts, nitrogen (N), phosphorus (P), potassium (K), sodium (Na), and organic matter (OM) (Table 1).

The experimental design was a split-split plot with soil materials as main plots, fertilizer treatments as sub plots, and soil-moisture treatments as sub-sub plots with four replications. The sub-sub

Table 2. Germination, seedling establishment, and ground cover from Super X Wheat grown on undisturbed soil and coal mine soil, with fertilizer and without fertilizer, and with optimum soil-moisture and with insufficient soil-moisture on the Black Mesa Coal Mine, Kayenta, Arizona in 1977 and 1978 (2-year average).

Soil material	Fertilizer treatment	Soil-moisture treatment	Seeds germinated in 1 m²	Seedlings established in 1 m²	Ground cover
			(no.)	(no.)	(%)
Undisturbed soil	Fertilized	Optimum	115 a†	58 a	96 a
		Insufficient	48 e	12 d	19 e
	Not fertilized	Optimum	95 b	29 c	79 c
		Insufficient	39 f	6 e	10 g
Coal mine soil	Fertilized	Optimum	81 c	32 b	86 b
		Insufficient	30 g	5 e	17 f
	Not fertilized	Optimum	64 d	13 d	67 d
		Insufficient	17 h	2 f	7 h
C.V. (%)			3	6	1
Significance of differences:					
Between soil materials			**	**	**
Between fertilizer treatments			**	**	**
Between soil-moisture treatments			**	**	**

** Significant at 1% level.
† Means followed by the same letter, between soil materials, between fertilizer treatments, and between soil-moisture treatments are not different at the 5% level of significance, using the Student-Newman-Keuls' Test.

plot size was 48 m² (8 m × 6 m). Fertilizer treatments were applied at planting time at rates of 0 and 560 kg/ha of ammonium phosphate using a conventional fertilizer spreader. The fertilizer application rate was determined from soil analyses which showed that unmined soil was low in nitrogen and both soil materials were low in phosphorus (Table 1). In April of each year, wheat was broadcast planted at the rate of 225 kg/ha with a cyclone seeder and covered with a spike-tooth harrow. Broadcasting was used in seeding operations because other conventional methods could not be employed due to the rough terrain.

Immediately after planting 2.5 cm of water for the insufficient and 5 cm of water for the optimum moisture treatments were applied using a sprinkler irrigation system with sprinkler heads spaced 9.14 m apart (in both directions).

The soil-moisture treatments consisted of (1) insufficient soil-moisture (20 cm of natural rainfall plus 30 cm of supplemental irrigation) and (2) optimum soil-moisture (20 cm of natural rainfall plus 60 cm of supplemental irrigation). The optimum moisture treatment was the total amount of water required to grow wheat to maturity without visual signs of moisture stress. There were no data available for water consumptive use and irrigation scheduling for wheat on the Black Mesa. Therefore, supplemental irrigation water was applied as needed throughout the growing season using the wheat plants in the insufficient moisture treatment as indicators of moisture requirement. When plants in the insufficient moisture treatments showed signs of wilting, they received 2.5 cm of irrigation water and plants in the optimum moisture treatment received 5 cm of irrigation. During the wheat growing season the evapotranspiration demand, especially from April to July, was at its maximum due to high temperature and high wind velocity. During this period, wheat required irrigation at weekly intervals.

The source of the irrigation water was runoff water from rains and snowmelt collected in a man-made reservoir. Thus, the irrigation water was superior in quality to well water, which contained high concentrations of soluble salts.

The following data were recorded for each plot each year: (1) seeds germinated (emerged) per unit area, (2) seedlings survived (4-weeks after planting) per unit area, (3) percent ground cover (percent of the total area covered by vegetation) at the end of the growing season. The standard analysis of variance was used to analyze all data. Means were compared using the Student-Newman-Keuls' test as described by Steel and Torrie (1960).

Results and Discussion

The average number of wheat seeds germinated per unit area differed between soil materials, between fertilizer treatments, and between soil-moisture treatments (Table 2). Average germination was higher in undisturbed soil than in coal mine soil, when fertilized than when not fertilized, and when optimum soil moisture was provided than when seeds received insufficient moisture for normal growth (Table 2).

Seedling establishment was higher in undisturbed soil than in coal mine soil, when fertilized than when not fertilized, and under optimum soil-moisture conditions than when seedlings were stressed for moisture (Table 2).

Average percent ground cover was higher in undisturbed soil than in coal mine soil, when fertilized than when not fertilized, and when optimum soil-moisture was provided than when vegetation was stressed for moisture (Table 2). Other wheat cultivars might respond differently than did Super X when grown in unmined soil and coal mine soil.

A high germination percentage usually results in a high seedlling establishment. High seedling establishment is important because many separate roots develop and form a more compact root community below the soil surface. This root community stabilizes the soil surface more effectively and makes it more resistant to the harmful effects of erosion and trampling by wildlife than a sparse root system. High seedling establishment creates a favorable habitat and food supply for wildlife and produces a more pleasing appearance for a disturbed area than does a low seedling establishment. The soil surface is protected against wind and water erosion by a high amount of ground cover. A high percent ground cover also improves the general appearance of disturbed areas.

Incorporation of organic matter from previously grown plant material into the soil surface aids in the revegetation of mine soils. Soil aeration and water-holding capacity are improved by the use of organic matter and an environment more suitable for germination and seedling establishment is created.

A more uniform application of mulching material can be obtained by growing wheat in mine wastes than by direct application of straw to mined areas. It is difficult to haul in straw and incorporate it into disturbed areas involving slopes because the straw tends to slide to the base of the slope. Once maximum vegetative growth is achieved, the wheat straw can be incorporated into the soil surface to create a more desirable soil medium into which adapted, perennial plant species may be established for the most effective disturbed land reclamation in semiarid environments. After two years of planting wheat and incorporating the residue into the soil surface, the authors observed great improvement in the structure of coal mine soil. Delaying the planting of perennial species for two years following coal mining permits the improvement of coal mine soil by physical and chemical forms of weathering. Time is also important in the development of soil microorganisms and in the mass stability of the spoil material.

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