VEGETATION RESPONSE TO ORGANIC SOIL AMENDMENTS ON COARSE TACONITE TAILING[1]

by

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Abstract. Mine land reclamation rules in Minnesota require that tailing dams be constructed and vegetated to control wind and water erosion for dam stability, safety, and dust control. Coarse taconite tailing used in dam construction tends to resist vegetation stabilization due to several adverse edaphic factors that make it difficult to establish and maintain a diverse and productive vegetative cover that will meet State standards. The Bureau of Mines, in cooperation with the Minnesota Department of Natural Resources -Division of Minerals, has implemented a series of experiments on coarse taconite tailing to study the effects of various organic residues on the establishment and maintenance of vegetative cover for site amelioration. At each of the tailing dam sites, changes that occurred in vegetative cover (live vegetation and its litter) as a result of experimental treatment was monitored. At the Minntac site, the total cover (mean of all treatment combinations) on the experimental site was 41 % with cover ranging from zero to 100 %. The type of organic amendment used, the rate at which the organic residues were applied, and the level of fertilization each had a significant effect on cover. The total number of plant species found at the Minntac site, including seeded vegetation, was 18. At the Eveleth Mines site, the total cover on the experimental site was 55 % with cover ranging from zero to 100 %. The type of organic amendment used, the rate at which the organic residues were applied, and the level of fertilization each had a significant effect on cover. Additionally, there were significant interactions between each of the main effects. The total number of plant species found at the Eveleth Mines site, including seeded vegetation was 38.

Additional Key Words: mine waste stabilization, compost, peat, fertilization, revegetation, cover

Introduction

The primary purpose for reclaiming mineral related mining waste sites is to stabilize them to prevent the wastes from being moved by wind and water. The principal methods used to stabilize mining waste are physical, chemical, and vegetative (Donovan, Felder, Rogers 1976; Hunt 1983; Dean, Froisland, Shirts 1986). Physical stabiliza-

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tion protects or isolates the waste materials from the environment by covering them with a physical barrier. Materials used include water for sprinkling to control dust, covering of the waste material with soil or overburden materials, mulches such as wood chips and straw, and organic amendments (Hunt 1983; Dean, Froisland, Shirts 1986). Other physical stabilization methods that have been used include windbreaks and spreading of a mixture of limestone chips and sodium silicate as a coating (Dean, Froisland, Shirts 1986).

Chemical stabilization involves incorporation of chemical compounds into mining related waste to form a wind or water resistant crust that will effectively stop wind or water erosion. Chemical binders are generally not long lasting and the erosion resistant crust is vulnerable to physical disruptions by contact. Once the surface is cracked or broken, erosion can undercut the crust and decrease surface stability (Dean, Froisland, Shirts 1986). Because the probability of physical disruption is high, chemical stabilization is not as durable as physical or vegetative stabilization; however, for temporary stabilization they are cost effective (Dean, Havens, Glantz 1974). Chemical stabilization can be used on sites unsuited for vegetative stabilization because of harsh climate, heavy metals, acidic or alkaline conditions, and on areas that lack available organic materials or lack suitable soil/overburden material. Dean and others (1986) list the best conditions and effective rates of application of chemical stabilizers to produce both wind and water resistant crusts.

Vegetative stabilization is generally a preferred reclamation method for mineral wastes; it is more permanent, has better esthetics, and allows for a wider range of end uses (Dean, Froisland, Shirts 1986). Stabilization of mine waste through vegetation establishment should accomplish one or more of the following goals: (1) fugitive dust control, (2) erosion control to prevent dam wall rupture, (3) erosion control to prevent runoff of surface particles and subsequent sediment disposition in water courses, (4) a reduction in water percolating through mine wastes, particularly acidic wastes and wastes contaminated by heavy metals, (5) aesthetic improvement of the waste areas, and (6) acceleration of natural succession on waste areas (Watkin and Watkin 1982).

Mineral mine wastes tend to resist vegetative stabilization due to several adverse factors, including: (1) adverse physical properties affecting structure, density, and water infiltration, (2) deficiencies of plant essential nutrients, (3) excessive salts and trace elements, (4) sand-sized particles that, when windblown, wind blast or bury the young plant seedlings, (5) lack of organic matter, (6) low cation-exchange capacity, (7) low water-holding capacity, (8) a dark color that absorbs and retains heat, (9) extremes in pH, and (10) little or no biological activity. To initiate vegetative stabilization of mine wastes it is necessary to ameliorate these physical, chemical, and biological characteristics.

Above- and below-ground plant organs provide effective protection from the physical effects of wind and water erosion. Vegetation grown on mineral wastes can reduce wind velocity, capture fugitive dust particles, reduce raindrop impact by intercepting the kinetic energy of rainfall, reduce water runoff by improving infiltration, reduce soil dispersal and movement through aggregation, and reduce or impede overland flow of water and sediment. As a result, a stable mineral waste may increase the amount of water available for plant growth and development.

Vegetative stabilization also improves the chemical and biological characteristics of the mine waste by increasing the organic matter content, nutrient supplying power, cation-exchange capacity, and biological activity of the waste material. These improvements can accelerate the development of a viable nutrient cycle and self-sustaining vegetative cover.

Historically, the approach used to stabilize coarse mineral wastes on Minnesota's Mesabi Iron Range has been to use inorganic fertilizers to establish vegetative cover. The research approach used by the Bureau of Mines on northern Minnesota coarse taconite tailing is the development of a combination of physical and vegetative stabilization techniques, specifically, additions of organic residues to enhance vegetative establishment.

Background

All current Minnesota iron ore production is in the form of taconite pellets, from seven taconite operations spread across the Mesabi Iron Range. Taconite iron ore concentration requires that the ore be crushed and finely ground before separation, and then made into pellets for shipment and processing in the steel mills. Two classes of permanent waste materials are produced by iron ore mining activities; overburden and tailing (Nater and Borovsky 1982). Overburden is the material removed from the open pits to allow access to the ore and consists of waste rock, glacial till, and soil materials.

Both coarse and fine tailing materials are produced in taconite ore processing. Fine tailing is impounded within dams, some of which are constructed with the coarse tailing removed early in the process. Coarse tailing is basically a silica material with a particle size range of sand and fine gravel. Today there are approximately 10,125 hectares of active tailing basins in northeastern Minnesota, an area that will be doubled when mining is completed by the year 2030 (Dewar and Berglund 1983).

Minnesota's mine land reclamation rules require mine operators to establish a permanent vegetative cover when tailing disposal sites are completed. The dam structures must be stabilized with vegetative cover within 3 years after final disturbance. If the dam slopes face primarily south or west, they must be stabilized within 5 years. In either case, living vegetation and its litter must provide 90 % cover of the ground. Within 10 years the dam must have a plant community with characteristics similar to the surrounding area; the vegetation must be self-sustaining, regenerating, or in a recognizable stage of succession which provides wildlife habitat or other alter-native land uses, such as pasture or timber land.

Coarse textured taconite tailing is not toxic to vegetation, but is extremely droughty and infertile (Dickinson 1972; Blake 1975). Permanent vegetation is inhibited by the tailing's low ability to adsorb and hold cations, inability to provide nitrogen and phosphorus, low water-holding capacity, and low numbers of microorganisms. As a result, the establishment of a satisfactory permanent vegetative cover on coarse taconite tailing has had limited success, with perhaps 40 to 60 % plant cover accomplished with typical revegetation techniques and annual maintenance (Shetron and Duffeck 1970; McDermond 1976; Dewar 1987).

Vegetation establishment may be accomplished with additions of organic matter. Incorporation of garbage compost into sandy soils improves soil physical and chemical properties (Pritchett and Fisher 1987). Compost-treated surface soils have higher organic matter contents and improved water-holding capacity (Fiskell, Pritchett, Maftoun, Smith 1979). By reducing pore space of coarse materials, the water-holding capacity and cation exchange capacity are increased, thus leading to increased yields (Mays, Terman, Duggan 1973). Norland and others (1990) showed that the incorporation of reed/sedge peat into coarse taconite tailing increased ground cover and biomass response of seeded vegetation. Additionally, the application of organic residues may serve as a source of microorganism inoculum.

In 1989, the Bureau, in cooperation with the Minnesota Department of Natural Resources - Division of Minerals, began a study to develop coarse tailing revegetation technology for the taconite industry of northern Minnesota, with future application to similar problems throughout the country. Since little natural soil material is available on site for amending coarse tailing dams, and the cost of such an effort would be prohibitive even if material was available, Bureau research led to testing the utilization of locally or readily available organic amendments to provide desirable soil qualities for the coarse tailing waste material. This research was expanded in 1990 to include coarse tailing test sites at two active mining operations in northern Minnesota, one experimenting with several types of organic residues and the other looking at the age of composted municipal solid waste (MSW) as a factor in vegetative response (Norland, Veith, Dewar 1991a,b).

The purpose of this paper is to report on vegetative establishment on coarse taconite tailing in northern Minnesota 2 years after organic residue treatment. Cover variables were measured on coarse tailing field plots treated with seven different organic residues in combination with fertilizer at two experimental sites on the Mesabi Iron Range.

Methods

Site Description

Studies were conducted at two active tailing basins in northern Minnesota; USX Corporation's, USS Steel Division, Minnesota Ore Operations (Minntac) taconite mine near Mt. Iron, Minnesota (325 km north of the Minneapolis-St. Paul metropolitan area) and Eveleth Mines Fairlane Plant 16 km south of Eveleth, Minnesota (300 km north of the Minneapolis-St. Paul metropolitan area).

Minntac uses coarse taconite tailing in the construction of dams for their 3,000 hectare tailing basin impoundment. The inner and outer dams, each about 46 m wide at the top, are constructed in a series of lifts utilizing trucks to haul the coarse tailing from the crushing and separation plants to the dam construction site. The slope of the dam is the angle of repose. The core of the tailing dam, the area between the inner and outer dams, is filled with fine tailing and is about 30 m wide. The total top width of the tailing dam is 122 m with an average height of about 10 m.

Eveleth Mines uses coarse taconite tailing in the construction of a dam for their 300 hectare tailing basin impoundment. Eveleth Mines coarse tailing dam was constructed in a series of lifts utilizing trucks to haul coarse tailing from the crushing and separation plants to the dam construction site. The height of the Eveleth Mines tailing dam is about 36 m with a width of about 20 m at the top. The slope of the dam is the angle of repose.

The mean annual precipitation for both study sites is 688 mm per year, with 66 % or 454 mm occurring as rainfall between May and September. The summer period consists of about 109 frost-free days with a seasonal air temperature varying from -38 °C (-36 °F) in the winter to 33 °C (91 °F) in the summer.

Experimental Design

Unbalanced factorial experiments arranged in randomized complete block designs with 3 replications were initiated in May 1990 at each tailing basin site. Each experiment included three levels of organic residue and three levels of fertilization. Control plots are included in each experiment. Treatment combinations were assigned to 2.5 by 4 m test plots at random within each replication.

At Minntac, three potentially available municipal solid waste (MSW) composts, varying in maturity, were surface-applied to the experimental plots as soil amendments. Each of the MSW composts were supplied by RECOMP, Inc., St. Cloud, Minnesota. The three MSW composts used were mature compost (windrowed for 180-days), intermediate aged compost (windrowed for 90-days), and immature compost (windrowed for 45-days). Each of the MSW composts were applied at rates of 10, 20, and 40 Mg ha^{-1} on a dry weight basis.

At Eveleth Mines, four potentially available organic residues were surface applied to experimental plots as soil amendments. The organic residues used and their origin were composted yard waste (RECOMP, Inc., St. Cloud, Minnesota), two mature MSW composts that had been windrowed for 180-days (RECOMP, Inc., St. Cloud, Minnesota). and reed/sedge peat (University of Minnesota - Duluth, Natural Resources Research Institute's Fens Research Facility located near Zim, Minnesota). The difference between the two MSW composts is that one contained soiled, disposable diaper residues in the amount typically found in MSW (2 % by weight), while the second MSW compost contained soiled, disposable diaper residues at an 8 % by weight level. Each of the organic amendments used at Eveleth Mines were applied at rates of 22.4, 44.8, and 89.6 Mg ha^{-1} on a dry weight basis.

Fertilizer applications at both experimental sites were based on the rate used for revegetation of northern Minnesota coarse taconite tailing; typically, 448 kg ha^{-1} of granular diammonium phosphate (DAP) with a grade of 18-46-0. The levels of fertilizer used in these experi-ments were 0, 224 (half the typical rate), and 448 kg ha^{-1} (typical rate) of DAP. The zero application of fertilizer was included to test the effects of each organic amendment alone on vegetative response.

The control plots consisted of no organic amendment or fertilizer application; no organic amendment, but fertilizer applied at one-half the rate typically used for coarse taconite tailing revegetation in northern Minnesota; and no organic amendment, but fertilizer applied at the typical rate.

Field Application

All experimental plots were installed May, 1990. Following the application of each organic amendment/rate combination, the plot was hand-raked to cover the 10 m^2 area. The appropriate fertilizer treatment was then broadcast onto the plots and all plots, including the controls, were rototilled to a depth of 15 cm. All seeding, soil, and analytical procedures followed in the field experiments are discussed in Norland and others (1991a). The chemical properties of the unamended Minntac and Eveleth Mines coarse taconite tailing and of the organic amendment used have been reported by Norland and others (1991a,b).

Vegetation Sampling and Analysis

Measurements of vegetation foliar cover, litter, and bare tailing were made using a cover-point optical point projection device. This instrument was designed for use in point-intercept cover sampling. The projection is made with large diameter objective and microscope optics magnified 5X. A microscope reticle is incorporated to provide a set of extremely fine cross hairs for projection of a point as dimensionless as possible. The cover-point optical point projector was mounted on a standard photographic tripod head. A move-able mirror was mounted on a 1 meter bar that had 11 stops placed every 10 cm to be used as measuring points. The bar was attached to the tripod and had a separate tripod for stability. Percent foliar cover, litter, and bare tailing were determined by looking through an eyepiece and recording hits or misses, as determined by the cross hairs, along the 11 sample points on the bar. Three multiple point samples were taken within each of the treatment plots.

Variations in vegetative foliar cover, litter, and bare soil among the unamended and amended treatments were analyzed using a 3-way analysis of variance at the 1 % and 5 % probability levels. The general linear models procedure (SAS Institute, Inc. 1988) was used to perform all analysis of variance tests. Multiple comparisons were made of the means using Tukey's studentized range test on all main effect means. Contrast statements were used to determine where mean differences occurred.

Results and Discussion

Vegetative cover, litter, and total cover were used to evaluate seeding success, vegetative establishment, and species composition on coarse taconite tailing after two growing seasons. Vegetative cover and litter were chosen as the variables to measure plant response to treatment since coarse taconite tailing reclamation success is determined by vegetative cover and its litter. Cover variables were significantly affected by the type of organic amendment used, rate of application, and fertilizer rate at both Minntac and Eveleth Mines (Table 1).

Vegetation, Litter and Bare Tailing

Minntac. Cover variables exhibited a statistically significant response to the main effects of MSW compost maturity, rate of application and rate of fertilizer application (Table 2). There were significant increases in cover variables when MSW composts were applied to coarse taconite tailing. Foliar cover increased significantly from 23.1 % in unamended tailing to 38.3 % when 45-day,

Table 1. Statistical significance of effects of type of organic amendment, rate of organic amendment application, and fertilizer rate on cover variables from Minntac and Eveleth Mines.

	Foliar Cover		Litter		Total Cover		Bare Tailing	
Factor	Minntac	Eveleth	Minntac	Eveleth	Minntac	Eveleth	Minntac	Eveleth
Type (T)	**	**	ns	ns	**	**	**	**
Rate (R)	**	**	ns	ns	**	**	**	**
T x R	*	**	ns	ns	*	**	*	**
Fertilizer (F)	**	**	**	**	**	**	**	**
T x F	*	**	*	ns	**	**	**	**
R x F	ns	*	ns	ns	ns	*	ns	*
T x R x F	ns	ns	ns	ns	ns	ns	ns	ns

*,** Significant at $P<0.05$ and 0.01, respectively. ns = not significant.

Table 2. Main effect cover (%) response on Minntac coarse taconite tailing.

Dependent	Municipal Solid Waste Compost				Rate				Fertilizer		
Variable	Control	45-day	90-day	180-day	0	10	20	40	0	224	448
Foliar Cover	23.1a	38.3b	32.8c	38.5b	23.1a	32.2b	37.0c	40.4c	19.6a	39.1b	46.8c
Litter	3.3a	5.8b	6.6b	5.9b	3.3a	5.7b	6.7b	5.9b	4.1a	6.6b	6.8b
Total Cover	26.4a	44.1b	39.4c	44.4b	26.4a	37.9b	43.7c	46.3c	23.7a	45.7b	53.6c
Bare Tailing	73.6a	55.9b	60.6c	55.6b	73.6a	62.1b	56.3c	53.7c	76.3a	54.3b	46.4c

[1] Control=no compost added, 45-day=45 days in compost windrow, 90-day=90 days in compost windrow, 180-day= 180 days in compost windrow.

[2] Amendment rates=0, 10, 20, and 40 Mg ha^{-1}.

[3] Fertilizer rates=0, 224, and 448 kg ha^{-1} of 18-46-0 fertilizer.

Means within the same row and main effect followed by the same letter are not significantly different at the 0.05 level.

32.8 % when 90-day, and 38.5 % when 180-day MSW composts were applied, while total cover signifi-cantly increased from 36.4 % in unamended tailing to 44.1 % when 45-day, 39.4 % when 90-day, and 44.4 % when 180-day MSW composts were applied. Both the 45- and 180-day MSW compost treatments had significantly higher foliar and total cover values than did the 90-day MSW compost treatment. The C:N ratios of coarse taconite tailing amended with 90-day MSW compost are higher than that of tailing amended with 45- and 180-day MSW composts (Norland, Veith, Dewar 1991b) suggesting nitrogen immobilization. Because of this condition, the 90-day MSW compost appears to be in an intermediate stage of decomposition/stabilization, thus limiting plant growth and development.

Mean percent litter was statistically higher in plots amended with MSW compost than in unamended plots, regardless of the age of the compost (Table 2). Percent litter was not significantly different between the various aged MSW composts. Litter in the 90-day MSW compost treatments was, however, higher than in the 45- or 180-day MSW compost treatments.

Increasing the rate of MSW compost applied significantly increased foliar and total cover (Table 2). Unamended coarse taconite tailing had a foliar cover value of 23.1 %, while applications of MSW compost significantly increased foliar cover to 32.2 % at 10 Mg ha^{-1}, 37.0 % at 20 Mg ha^{-1}, and 40.4 % at 40 Mg ha^{-1} and total cover to 37.9 % at 10 Mg ha^{-1}, 43.7 % at 20 Mg ha^{-1}, and 46.3 % at 40 Mg ha^{-1}. As the application rate increased, there was a corresponding increase in both foliar and total cover. Although foliar and total cover was higher at 40 Mg ha^{-1}, differences in foliar and total cover at the 20 and 40 Mg ha^{-1} application rates were not significant.

Increasing the rate of application of 18-46-0 (DAP) fertilizer from 0 to 448 kg ha^{-1} significantly increased foliar and total cover. Unfertilized coarse taconite tailing had a foliar cover value of 19.6 %, while applications of 224 kg ha^{-1} DAP significantly increased foliar cover to 39.1 % and applications 448 kg ha^{-1} DAP significantly increased foliar cover to 46.8 %. The difference in cover between the 224 and 448 kg ha^{-1} fertilizer treatments is significant. This fertilizer effect was similar to the first year fertilizer effect found by Norland and others (1991b). Total cover showed a significant increase from 23.7 % in unfertilized plots to 45.7 % in plots fertilized with 224 kg ha^{-1} DAP and 53.6 % in plots fertilized with 448 kg ha^{-1} DAP.

Mean percent litter was statis-tically higher in plots amended with MSW compost and fertilizer than in unamended plots (Table 2). Although litter was higher in amended plots, there was no significant difference in litter between the types of MSW compost used, the rates at which MSW compost was applied, or the rate at which DAP fertilizer was applied.

Mean bare tailing decreased significantly when amendments were used (Table 2). The decrease in bare tailing with the application of amendments suggests that MSW compost and fertilizer applications are providing the nutrients for plant establishment and growth. The results suggest that foliar, litter, and total cover increase and bare tailing decrease with the application of MSW compost and fertilizer. Best results were generally achieved with the higher rates of both mature MSW compost and DAP fertilizer. Mean total cover at the Minntac site across all treatments was 41 %, this is an overall increase of 7 percent-age points from 1991 (Norland, Veith, Dewar 1991b).

There is a significant interaction between MSW compost age and rate of MSW application (Table 3). Increasing the rate of 45-day MSW compost from 0 to 10, 20, or 40 Mg ha^{-1} significantly increased both foliar and total cover; however, there is no significant difference in either foliar or total cover between 10, 20, and 40 Mg ha^{-1} when 45-day MSW compost was used as the amendment.

Increasing the application rate of 90- and 180-day MSW composts from 0 to 40 Mg ha^{-1} significantly increased foliar and total cover. When 10 or 20 Mg ha^{-1} of 90-day MSW compost was applied, there was a nonsignificant increase in foliar cover from 23.1 % at

Table 3. Interaction effect of type of organic amendment and rate of application on cover (%) response on Minntac coarse taconite tailing.

Dependent Variable	45-day				90-day				180-day			
	0	10	20	40	0	10	20	40	0	10	20	40
Foliar Cover	23.1a	33.7b	39.0b	42.3b	23.1a	29.7ab	33.1ab	35.6b	23.1a	33.3ab	38.8b	43.3b
Litter	3.3	5.5	6.8	5.2	3.3	5.8	6.7	7.3	3.3	5.8	6.5	5.3
Total Cover	26.4a	39.2b	45.8b	47.5b	26.4a	35.5ab	39.8b	42.9b	26.4a	39.1b	45.3b	48.6b
Bare Tailing	73.6a	60.8b	54.2b	52.5b	73.6a	64.5ab	60.2b	57.1b	73.6a	60.9b	54.7b	51.4b

[1] 0=no compost added, 45-day=45 days in compost windrow, 90-day=90 days in compost windrow, 180-day= 180 days in compost windrow.
[2] Amendment rates=0, 10, 20, and 40 Mg ha^{-1}.
Means within the same row and age of MSW compost followed by the same letter are not significantly different at the 0.05 level.

0 Mg ha^{-1} MSW compost to 29.7 % at 10 Mg ha^{-1} and 33.1 % at 20 Mg ha^{-1}; however when 40 Mg ha^{-1} of 90-day MSW was applied, there was a significant increase in foliar cover to 35.6 %. The difference in foliar cover between 90-day MSW compost applied at 10, 20, or 40 Mg ha^{-1} is not significant. When 10 Mg ha^{-1} of 90-day MSW compost was applied, there was a insignificant increase in total cover from 26.4 % at 0 Mg ha^{-1} MSW compost to 35.5 %. The application of 20 and 40 Mg ha^{-1} of 90-day MSW compost significantly increased total cover from 26.4 % at 0 Mg ha^{-1} to 39.8 % at 20 Mg ha^{-1} and 42.9 % at 40 Mg ha^{-1}. There was no significant difference in total cover between applications of 10, 20, or 40 Mg ha^{-1} of 90-day MSW compost.

When 10 Mg ha^{-1} of 180-day MSW compost was applied, there was an insignificant increase in foliar cover from 23.1 % at 0 Mg ha^{-1} MSW compost to 33.3 %; however, when 20 or 40 Mg ha^{-1} of 180-day MSW was applied, there was a significant increase in foliar cover from 23.1 % at 0 Mg ha^{-1} to 38.8 % at 20 Mg ha^{-1} and 43.3 % at 40 Mg ha^{-1}. The difference in foliar cover between 180-day MSW compost applied at 10, 20, or 40 Mg ha^{-1} is nonsignificant. The application of 10, 20, and 40 Mg ha^{-1} of 180-day MSW compost significantly increased total cover from 26.4 % at 0 Mg ha^{-1} to 39.1 % at 10 Mg ha^{-1}, 45.3 % at 20 Mg ha^{-1} and 48.6 % at 40 Mg ha^{-1}. There is no significant difference in total cover between the three rates of 180-day MSW compost.

Litter cover values were not significantly affected by the interaction between MSW compost age and rate of MSW application (Table 3). As the rate of MSW compost increased from 0 to 40 Mg ha^{-1}, there were significant decreases in the percentage of bare tailing. In general, there were no significant differences in percent bare tailing between the 10, 20, and 40 Mg ha^{-1} rates of MSW compost application. One exception is the insignificant decrease in percentage of bare tailing between 0 Mg ha^{-1} and 10 Mg ha^{-1} application of 90-day MSW compost.

There is a significant interaction between MSW compost age and rate of fertilizer application (Table 4). Increasing the rate of fertilization from 0 to 448 kg ha^{-1}

Table 4. Interaction effect of type of organic amendment and fertilizer rate on cover (%) response on Minntac coarse taconite tailing.

Dependent	Control			45-day			90-day			180-day		
Variable	0	224	448	0	224	448	0	224	448	0	224	448
Foliar Cover	3.0a	33.1b	33.2b	20.7a	42.5b	51.7b	17.7a	35.3b	45.5b	25.9a	41.6b	47.8b
Litter	3.0	3.5	3.5	3.0a	7.8b	6.7ab	4.3a	6.2ab	9.3b	5.3	6.8	5.5
Total Cover	6.0a	36.6b	36.7b	23.7a	50.3b	58.4c	22.0a	41.5b	55.1c	31.2a	48.4b	53.3b
Bare Tailing	94.0a	63.4b	63.3b	76.3a	49.7b	41.6c	78.0a	58.5b	44.9c	68.8a	51.6b	46.7b

[1] Control=no compost added, 45-day=45 days in compost windrow, 90-day=90 days in compost windrow, 180-day= 180 days in compost windrow.

[2] Fertilizer rates=0, 224, and 448 kg ha^{-1} of 18-46-0 fertilizer.

Means within the same row and age of MSW compost followed by the same letter are not significantly different at the 0.05 level.

within each amendment type (zero, 45-, 90-, and 180-day MSW compost) resulted in a significant increase in foliar and total cover; however, there are no significant differences in foliar cover between the 224 and 448 kg ha^{-1} fertilizer treatments within each amendment type. There are significant differences in total cover within the 45-day and 90-day MSW compost treatments between the 224 and 448 kg ha^{-1} treatments.

Increasing the application rate of fertilizer within the control, 45-day, 90- and 180-day MSW composts from 0 to 448 kg ha^{-1} significantly increased foliar cover. When no fertilizer was applied the percent foliar cover was 3.0 % in the control, 20.7 in the 45-day MSW compost, 17.7 % in the 90-day MSW compost, and 25.9 % in the 180-day MSW compost. The addition of 224 or 448 kg ha^{-1} of DAP fertilizer resulted in significant increases in foliar cover in each organic amendment type; however, increases in cover between fertilizer rates within each organic amendment were not significant. When the rate of fertilizer application was increased from 0 to 224 kg ha^{-1} and from 224 kg ha^{-1} to 448 kg ha^{-1} within the 45- and 90-day MSW composts, there was a significant increase in total cover. There was no significant difference in total cover between the 224 and 448 kg ha^{-1} fertilizer treatments in the control or 180-day MSW compost treatments.

Litter cover values were significantly affected by the interaction between MSW compost type and rate of fertilization application (Table 4). As the rate of fertilizer application increased in the 45- and 90-day MSW compost treatments from 0 to 224 or 0 to 448 kg ha^{-1}, there was a significant increase in the amount of plant litter. There were no significant difference in litter cover within the 45- and 90-day MSW compost treatments between the 224 and 448 kg ha^{-1} DAP fertilizer treatments.

Litter showed a insignificant increase in both the control and 180-day MSW compost treatment with fertilizer additions. As the rate of fertilizer increased from 0 to 448 kg ha^{-1} within each compost type, there were significant decreases in the percentage of bare tailing. There were no significant differences in percent bare tailing between the 224 and 448 kg ha^{-1} fertilizer application rate within the control and 180-day MSW compost; however, the percentage of bare tailing between the 224 and 448 kg ha^{-1} fertilizer treatments within the 45- and 90-day MSW compost treatments showed a significant decrease.

Eveleth Mines. Cover variables exhibited a statistically significant response to the main effects of organic residue type, rate of application and rate of fertilizer application (Table 5). There were significant increases in cover variables when organic residues were applied to coarse taconite tailing. Foliar cover increased significantly from 18.5 % in untreated tailing to 48.0 % when MSW compost with added diaper residue was applied, 49.0 % when MSW compost without added diaper residue was applied, 50.6 % when reed/sedge peat was applied, and 55.1 % when composted yard waste was applied. Total cover significantly increased from 24.8 % in unamended tailing to 54.7 % when MSW compost with added diaper residue was applied, 55.2 % when MSW compost without added diaper residue was applied, 56.4 % when reed/sedge peat was added, and 62.4 % when composted yard waste was added.

There was a significant difference in foliar and total cover between the different organic residue types used after two growing seasons. All of the organic residue types resulted in significantly higher foliar and total cover values than did the control. There were also significant differences between the organic residue types used, with composted yard waste resulting in significantly higher foliar and total cover percentages than MSW composts with and without added diaper residue and the reed/sedge peat. There were no significant differences in cover variables between the MSW composts with and without added diaper residues and the reed/sedge peat. Mean percent litter was not statistically different between the control plots and plots amended with organic residues (Table 5).

Each organic residue type used showed an increase in percent total cover from the first to second growing season, while the control had a significant decrease from the first to second growing season. Total cover in control plots decreased from 36.4 % in the first growing season to 24.8 % in the second. Additions of MSW compost with added diaper residue resulted in an insignificant increase in total cover from 52.9 to 54.7 %, while additions of MSW compost without added diaper residue, reed/sedge peat, and compost yard waste resulted in significant increases in total cover from 49.8 to 55.2 %, 50.7 to 56.4 %, and 46.5 to 62.4 %, respectively.

Increasing the rate of organic residue applied significantly increased foliar and total cover (Table 5). Unamended coarse taconite tailing had a foliar cover value of 18.5 %, while applications of organic residues compost significantly increased foliar cover to 42.7 % at 22.4 Mg ha^{-1}, 49.9 % at 44.8 Mg ha^{-1}, and 59.4 % at 89.6 Mg ha^{-1}. Total cover increased from 24.8 % in unamended tailing to 49.4 % at 22.4 Mg ha^{-1}, 56.2 % at 44.8 Mg ha^{-1}, and 65.9 % at 89.6 Mg ha^{-1}.

At each rate of amendment application, there was an increase in percent total cover from the first to second growing season, while the control had a significant decrease from the first to second

Table 5. Main effect cover (%) response on Eveleth Mines coarse taconite tailing.

Dependent	Organic Amendment					Rate				Fertilizer		
Variable	C	YW	MSW-W	MSW-O	P	0	22.4	44.8	89.6	0	224	448
Foliar Cover	18.5a	55.1b	48.0c	49.0c	50.6c	18.5a	42.7b	49.9c	59.4d	39.3a	52.1b	53.2b
Litter	6.3	7.3	6.7	6.2	5.8	6.3	6.7	6.3	6.5	4.7a	6.9b	7.9b
Total Cover	24.8a	62.4b	54.7c	55.2c	56.4c	24.8a	49.4b	56.2c	65.9d	44.0a	59.0b	61.1b
Bare Tailing	75.2a	37.6b	45.3c	44.8c	43.6c	75.2a	50.6b	43.8c	34.1d	56.0a	41.0b	38.9b

[1] C=Control no compost added, YW=Composted Yard Waste, MSW-W=Municipal Solid Waste Compost with diaper residue added to 8 %, MSW-O Municipal Solid Waste Compost with diaper residue at 2 %, P=Reed/Sedge Peat. All composts are mature - windrowed for 180 days.

[2] Amendment rates=0, 22.4, 44.8, and 89.6 Mg ha^{-1}.

[3] Fertilizer rates=0, 224, and 448 kg ha^{-1} of 18-46-0 fertilizer.

Means within the same row and main effect followed by the same letter are not significantly different at the 0.05 level.

growing season. Total cover in control plots decreased from 36.4 % in the first growing season to 24.8 % in the second. At 22.4 Mg ha^{-1} there was an insignificant increases in total cover from 45.5 to 49.4 %, while at application rates of 44.8 and 89.6 Mg ha^{-1} there were significant increase in total cover from 49.1 to 56.2 % at 44.8 Mg ha^{-1} and from 55.5 to 65.9 % at 89.6 Mg ha^{-1}.

Increasing the rate of application of 18-46-0 (DAP) fertilizer from 0 to 448 kg ha^{-1} significantly increased foliar and total cover. Unfertilized coarse taconite tailing had a foliar cover value of 39.3 %, while applications of 224 kg ha^{-1} DAP significantly increased foliar cover to 52.1 % and applications of 448 kg ha^{-1} DAP significantly increased foliar cover to 53.2 %. The difference in cover between the 224 and 448 kg ha^{-1} fertilizer treatments was not significant. This fertilizer affect is different than the first year fertilizer affect found by Norland and others (1991a), where increasing DAP applications from 224 kg ha^{-1} to 448 kg ha^{-1} significantly increased foliar cover. Total cover from the second growing season showed a significant increase from 44.0 % in unfertilized plots to 59.0 % in plots fertilized with 224 kg ha^{-1} DAP and 61.1 % in plots fertilized with 448 kg ha^{-1} DAP.

Mean percent litter was statistically higher in plots amended with fertilizer than in unfertilized plots (Table 5). Although litter is higher in fertilized plots, there is no significant difference in litter between the higher rates of DAP fertilizer used.

The decrease in bare tailing area with the application of amendments (Table 5) suggests that organic residues and fertilizer applications are needed to provide nutrients and retain moisture for plant establishment and growth. The results suggest that foliar, litter, and total cover can be increased and bare tailing decreased with the applications of mature MSW compost, reed/sedge peat, or composted yard waste, at a rate of 89.6 Mg ha^{-1}, with 224 kg ha^{-1} of DAP fertilizer. Mean total cover at the Eveleth Mines site across all treatments was 55 %, this is an overall increase of 6 percentage points from 1991 (Norland, Veith, Dewar 1991a).

There was a significant interaction between the type of organic residue used and the rate of application (Table 6). Increasing the rate of an organic residue from 0 to 22.4, 44.8, or 89.6 Mg ha^{-1} significantly increased both foliar and total cover. There were also significant differences in foliar or total cover between the 22.4, 44.8, and 89.6 Mg ha^{-1} within each organic residue type used as an amendment.

Increasing the application rate of composted yard waste from 0 to 22.4, 44.8, or 89.6 Mg ha^{-1} signifi-cantly increased foliar and total cover (Table 6). When composted yard waste was applied, there was a significant increase in foliar cover from 18.5 % at 0 Mg ha^{-1} to 48.6 % at 22.4 Mg ha^{-1}, 58.6 % at 44.8 Mg ha^{-1}, and 58.1 % at 89.6 Mg ha^{-1}. There was no significant difference in foliar cover between the 44.8 and 89.6 Mg ha^{-1} rates of application, but both were significantly higher than the 22.4 Mg ha^{-1} treatment level. The same type of response was found for total cover where total cover significantly increased from 24.8 % in unamended tailing to 55.6 % at 22.4 Mg ha^{-1}, 65.1 % at 44.8 Mg ha^{-1}, and 66.4 % at 89.6 Mg ha^{-1}. Again, there was no signifi-cant difference in total cover between the 44.8 and 89.6 Mg ha^{-1} application rates.

Increasing the application rate of MSW compost with added diaper residue and reed/sedge peat from 0 to 22.4, 44.8, or 89.6 Mg ha^{-1}, resulted in the same type of significant response with respect to foliar and total cover. When MSW compost with added diaper residue was applied, there was a significant increase in foliar cover from 18.5 % at 0 Mg ha^{-1} to 41.5 % at 22.4 Mg ha^{-1}, 45.2 % at 44.8 Mg ha^{-1}, and 57.4 % at 89.6 Mg ha^{-1}. When reed/sedge peat was applied, there was a significant increase in foliar cover from 18.5 % at 0 Mg ha^{-1} to 42.5 % at 22.4 Mg ha^{-1}, 48.3 % at 22.4 Mg ha^{-1}, and 60.9 % at 89.6 Mg ha^{-1}.

There was no significant difference in foliar cover between the 22.4 and 44.8 Mg ha^{-1} rates of application for both organic residue types, but both rates for each organic residue type are significantly lower than the 89.6 Mg ha^{-1} treatment level.

The same type of response was found for total cover that increased significantly from 24.8 % in unamended tailing to 48.5 % at 22.4 Mg ha^{-1}, 51.2 % at 44.8 Mg ha^{-1}, and 64.6 % at 89.6 Mg ha^{-1} for MSW compost with added diaper residue, and 49.0 % at 22.4 Mg ha^{-1}, 54.3 % at 44.8 Mg ha^{-1}, and 65.7 % at 89.6 Mg ha^{-1} for the reed/sedge peat amendment. Again, there was no significant difference in total cover between the 22.4 and 44.8 Mg ha^{-1} application rates for both organic residue types, but total cover at both rates was significantly lower than total cover at the 89.6 Mg ha^{-1}.

Increasing the application rate of MSW compost without added diaper residue from 0 to 22.4, 44.8, or 89.6 Mg ha^{-1} significantly increased foliar and total cover (Table 6). When MSW compost without added diaper waste was applied, there was a significant increase in foliar cover from 18.5 % at 0 Mg ha^{-1} to 38.0 % at 22.4 Mg ha^{-1}, 47.6 % at 44.8 Mg ha^{-1}, and 61.5 % at 89.6 Mg ha^{-1}. There was a significant increase in foliar

Table 6. Interaction effect of type of organic amendment and rate of application on cover (%) response on Eveleth Mines coarse taconite tailing.

Dependent	Composted Yard Waste				MSW-W				MSW-O				Reed/Sedge Peat			
Variable	0	22.4	44.8	89.6	0	22.4	44.8	89.6	0	22.4	44.8	89.6	0	22.4	44.8	89.6
Foliar Cover	18.5a	48.6b	58.6c	58.1c	18.5a	41.5b	45.2b	57.4c	18.5a	38.0b	47.6c	61.5d	18.5a	42.5b	48.3b	60.9c
Litter	6.3	7.0	6.5	8.3	6.3	7.0	6.0	7.2	6.3	6.2	6.8	5.5	6.3	6.5	6.0	4.8
Total Cover	24.8a	55.6b	65.1c	66.4c	24.8a	48.5b	51.2b	64.6c	24.8a	44.2b	54.4c	67.0d	24.8a	49.0b	54.3b	65.7c
Bare Tailing	75.2a	44.4b	34.9c	33.6c	75.2a	51.5b	49.8b	35.4c	75.2a	55.8b	45.6c	33.0d	75.2a	51.0b	45.7b	34.3c

[2] MSW-W—Municipal Solid Waste Compost with diaper residue added to 8%.
[3] MSW-O—Municipal Solid Waste Compost with diaper residue at 2 %.
[4] Amendent rates—0, 22.4, 44.8, and 89.6 Mg ha^{-2}.
Means within the same row and organic amendment followed by the same letter are not significantly different at the 0.05 leve

Table 7. Interaction effect of type of organic amendment and fertilizer rate on cover (%) response on Eveleth Mines coarse taconite tailing.

Dependent	Control			Composted Yard Waste			MSW-W			MSW-O			Reed/Sedge Peat		
Variable	0	224	448	0	224	448	0	224	448	0	224	448	0	224	448
Foliar Cover	6.5a	24.1b	25.1b	52.3	58.0	54.9	36.7a	52.9b	54.5b	42.0a	51.6ab	53.6b	37.4a	55.3b	59.1b
Litter	3.5	6.0	9.5	5.5	7.7	8.7	5.2	7.7	7.3	4.2	6.2	8.2	4.2	6.3	6.8
Total Cover	10.0a	30.1b	34.6b	57.8a	65.7b	63.6ab	41.9a	60.6b	61.8b	46.2a	57.8b	61.8b	41.6a	61.6b	65.9b
Bare Tailing	90.0a	69.9b	65.4b	42.2a	34.3b	36.4ab	58.1a	39.4b	38.2b	53.8a	42.2b	38.2b	58.4a	38.4b	34.1b

[2] MSW-W—Municipal Solid Waste Compost with diaper residue added to 8%.
[3] MSW-O—Municipal Solid Waste Compost with diaper residue at 2 %.
[4] Fertilizer rates—0, 224, and 448 kg ha^{-2}.
Means within the same row and organic amendment followed by the same letter are not significantly different at the 0.05 level

cover as the rate of application of MSW compost without added diaper residue increased. The same type of response was found for total cover where total cover significantly increased from 24.8 % in unamended tailing to 44.2 % at 22.4 Mg ha^{-1}, 54.4 % at 44.8 Mg ha^{-1}, and 67.0 % at 89.6 Mg ha^{-1}. Again, there was a significant difference in total cover between each applica-tion rate. The results show that each organic residue type responds differently to each rate of application, but, in each residue type, the highest foliar and total cover values were achieved at the highest rate of amendment application.

Litter cover values were not significantly affected by the interaction between type of organic residue and the rate of application (Table 6). As the rate of organic residue application increased from 0 to 89.6 Mg ha^{-1}, there was a significant decrease in the percentage of bare tailing. There were significant differences in percent bare tailing between the rates of organic residue application within each type of organic residue, and these differences were opposite those of the total cover variable. For example, the 0 Mg ha^{-1} application rate had a significantly higher bare tailing value than did the 22.4, 44.8, or 89.6 Mg ha^{-1} rates of organic residues.

There was a significant interaction between organic residue type and rate of fertilizer application (Table 7). Increasing the rate of fertilization from 0 to 448 kg ha^{-1} within the plots without organic residue, MSW compost with and without added diaper residue, and reed/sedge peat treatments all resulted in a significant increase in foliar and total cover; however, there were no significant differences in foliar cover between the 224 and 448 kg ha^{-1} fertilizer treatments within each amendment type. There was no significant difference in foliar cover when fertilizer was added to composted yard waste; however, there was a significant difference in total cover when fertilizer was added to composted yard waste. It appears that 224 kg ha^{-1} of DAP fertilizer with the addition of an organic residue was enough to increase foliar and total cover significantly over total cover with no amendment or the amendments alone. Litter cover values were not significantly affected by the interaction between MSW compost type and rate of fertilization application (Table 7).

As the rate of fertilizer application increased from 0 to 224 or 448 kg ha^{-1}, there were significant decreases in the percentage of bare tailing. There were no significant differences in percent bare tailing between the rates of fertilizer application within each type of organic residue.

There is a significant interaction between the rate of organic residue application and rate of fertilizer application (Table 8). Increasing the rate of fertilization from 0 to 448 kg ha^{-1} within the 0, 22.4, 44.8, and 89.6 Mg ha^{-1} application rates, resulted in a significant increase in foliar and total cover; however, there were no significant differences in foliar or total cover between the 224 and 448 kg ha^{-1} fertilizer treatments within each rate of organic residue application. It appears that 224 kg ha^{-1} of DAP fertilizer within each rate of organic residue application was enough to increase foliar and total cover over cover with no fertilizer addition. Litter cover values were not significantly affected by the interaction between the rate of organic residue applications and rate of fertilization application (Table 8).

As the rate of fertilizer application increased from 0 to 224 or 448 kg ha^{-1}, there were significant decreases in the percentage of bare tailing. There were no significant differences in percent bare tailing between the rates of fertilizer application within each rate of organic residue application.

Plant Species Present

The plant species present at the Minntac and Eveleth Mines experimental sites are listed in Tables 9 and 10. At Minntac, not including seeded vegetation, there was an increase in the number of species present. After the first growing season there were 6 additional species at Minntac, and after the second growing season there were a total of 13 additional species. Included in this list are early (volunteer) and late (native) successional species (Table 9).

At Eveleth Mines, not including the seeded vegetation, there was also an increase in the number of species present. After the first growing season there were 15 other species, while after the second growing season there were a total of 33 additional species. The differ-ence in numbers of volunteer species between USX and Eveleth Mines was primarily due to the native seed bank in the reed/sedge peat, some species were also contributed through the application of composted yard waste. Included in this list are early (volunteer) and late (native) successional species. It appears that a productive, diverse, self-sustaining plant communities are beginning to develop at both Minntac and Eveleth Mines with the addition of organic residues. Further monitoring is necessary to determine if this is occurring.

Conclusion

The second-year results of this long-term study suggests that the organic residues used at Minntac and Eveleth Mines ameliorate the harsh chemical, physical, and biological characteristics of coarse taconite tailing, resulting in an environment that is more amenable for plant growth and development. The organic residues used provided a source of organic matter and a slow-release source of macro- and micronutrients for plant nutrition and microbial growth (particularly nitrogen and phosphorus). Additionally, the organic residues help to retain moisture within the tailing. Immobilization of nitrogen may be a problem if the organic residue has not stabilized, such as the intermediate-aged (90-days in windrow) MSW compost at Minntac; however, additions of inorganic nitrogen with the other types of organic residue appears to have slowed or inhibited nitrogen immobilization. Results obtained after two growing seasons suggest that foliar, litter, and total plant cover will increase and bare tailing decrease when composted yard wastes, reed/sedge peat, and mature MSW composts are used as organic amendments. Best results were obtained when these amendments were applied at the rate of 89.6 Mg ha^{-1}, with at least 224 kg ha^{-1} DAP fertilizer.

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Table 8. Interaction effect of rate of organic amendment application and fertilizer rate on cover response (%) on Eveleth Mines coarse taconite tailing.

Dependent		0			22.4			44.8			89.6	
Variable	0	224	448	0	224	448	0	224	448	0	224	448
Foliar Cover	6.5a	24.1b	25.1b	31.5a	47.7b	48.8b	41.8a	52.6b	55.4b	52.9a	63.1b	62.3b
Litter	3.5	6.0	9.5	4.6	7.8	7.6	4.6	6.4	8.0	5.0	6.8	7.6
Total Cover	10.0a	30.1b	34.6b	36.1a	55.5b	56.7b	46.4a	59.0b	63.4b	57.9a	69.9b	69.9b
Bare Tailing	90.0a	69.9b	65.4b	63.9a	44.5b	43.3b	53.6a	41.0b	36.6b	42.1b	30.1b	30.1b

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[1] Amendment rates=0, 22.4, 44.8, and 89.6 Mg ha^{-1}.

[2] Fertilizer rates=0, 224, and 448 kg ha^{-1}.

Means within the same row and application rate followed by the same letter are not significantly different at the 0.05 level.

Table 9. Plant species present on the Minntac experimental site.

Seeded Vegetation
- Grasses
  - smooth brome (*Bromus inermis* Leyss.)
  - red fescue (*Festuca rubra* L.)
  - perennial ryegrass (*Lolium perenne* L.)
- Leguminous Forbs
  - alfalfa (*Medicago sativa* L.)
- Non-Leguminous Forbs
  - buckwheat (*Fagopyrum esculentum* Moench)

Volunteer Vegetation
- Grasses
  - red top (*Agrostis alba* L.)
  - yellow foxtail (*Setaria lutescens* (Weigel) Hubb.)
- Leguminous Forbs
  - yellow sweetclover (*Melilotus officinalis* Lam.)
  - white clover (*Trifolium repens* L.)
- Non-Leguminous Forbs
  - mouse-ear chickweed (*Cerastium vulgatum* L.)
  - ox-eye daisy (*Chrysanthemum leucanthemum* L.)
  - lambsquarters (*Chenopodium album* L.)
  - hawk's-beard (*Crepis tectorum* L.)
  - horseweed (*Erigeron canadensis* L.)
  - kochia (*Kochia scoparia* (L.) Roth.)
  - prostrate knotweed (*Polygonum aviculare* L.)
  - smallflower buttercup (*Ranunculus abortivus* L.)
  - sheep sorrel (*Rumex acetosella* L.)

Table 10. Plant species present on the Eveleth Mines experimental site.

- Seeded Vegetation
  - *Grasses*
    - smooth brome (*Bromus inermis* Leyss.)
    - red fescue (*Festuca rubra* L.)
    - perennial ryegrass (*Lolium perenne* L.)
  - *Leguminous Forbs*
    - alfalfa (*Medicago sativa* L.)
  - *Non-Leguminous Forbs*
    - buckwheat (*Fagopyrum esculentum* Moench)

- Volunteer Vegetation
  - *Grasses*
    - quackgrass (*Agropyron repens* (L.) Beauv.)
    - red top (*Agrostis alba* L.)
    - crabgrass (*Digitaria sanguinalis* (L.) Scop.)
    - Canada wild rye (*Elymus canadensis* L.)
    - Canada bluegrass (*Poa compressa* L.)
    - Kentucky bluegrass (*Poa pratensis* L.)
    - yellow foxtail (*Setaria lutescens* (Weigel) Hubb.)
    - green foxtail (*Setaria viridis* (L.) Beauv.)
  - *Leguminous Forbs*
    - yellow sweetclover (*Melilotus officinalis* Lam.)
    - red clover (*Trifolium pratense* L.)
    - white clover (*Trifolium repens* L.)
  - *Non-Leguminous Forbs*
    - velvetleaf (*Abutilon theophrasti* Medic.)
    - common yarrow (*Achillea millefolium* L.)
    - prostrate pigweed (*Amaranthus graecizans* L.)
    - rough pigweed (*Amaranthus retroflexus* L.)
    - yellow rocket (*Barbarea vulgaris* R. Br.)
    - Indian mustard (*Brassica juncea* (L.) Cross.)
    - shepard's-purse (*Capsella bursa-pastoris* (L.) Medic.)
    - mouse-ear chickweed (*Cerastium vulgatum* L.)
    - lambsquarters (*Chenopodium album* L.)
    - ox-eye daisy (*Chrysanthemum leucanthemum* L.)
    - Canada thistle (*Cirsium arvense* (L.) Scop.)
    - hawk's-beard (*Crepis tectorum* L.)
    - horseweed (*Erigeron canadensis* L.)
    - kochia (*Kochia scoparia* (L.) Roth.)
    - white campion (*Lychnis alba* Mill.)
    - field mint (*Mentha arvensis* L.)
    - black bindweed (*Polygonum convolvulus* L.)
    - common smartweed (*Polygonum pensylvanicum* L.)
    - rough cinquefoil (*Potentilla norvegica* L.)
    - common skullcap (*Scutellaria epilobiifolia* Muhl.)
    - sheep sorrel (*Rumex acetosella* L.)
    - goat's-beard (*Tragopogon dubius* Scop.)

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