Sand Dune Erosion Control at Provincetown, Mass.

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Stabilization of sand dunes is discussed, showing results of the most economical and feasible methods for the Provincetown area. Machine planting of beach grass with a spacing of 18 by 36 in. and the use of fertilizer is an excellent method for revegetating dunes. Several species of grasses have been screened for direct seeding on dune areas. Panicum amarulum, tall fescue and weeping love grass have produced satisfactory results. The use of various mulches in grass establishment for direct seeding has been of little value.

•CAPE COD is a scenic peninsula in the form of a bent arm extending 70 mi into the Atlantic Ocean. The sand dunes at Provincetown and Truro, Mass., cover 8 sq mi and are perhaps the most spectacular dunes on the Cape (1). From the ocean side, the dunes rise above the beach; on the inland side, they merge with the salt marshes. Several lines of dunes with low valleys parallel to the coast make up the inland dunes which, in some cases, are 50 to 60 ft high. These inland dunes are generally bare and consist of sand piled up by northerly winds. The dunes are continuously shifting, covering roads, swamps and wooded areas. During the past few years, some 10,000 cu yd of sand have been removed annually from a section of US 6 near Provincetown. In the spring of 1963, another inland dune in the immediate area had reached the highway, and within a few years a third rapidly creeping dune will be deposited on the highway. If these dunes are not stabilized within a few years they will fan out and deposit sand along the highway for a distance of about 1 mi.

The goal in controlling shifting and unstable dunes is to establish a permanent cover of vegetation. Because of the differences in vegetation and the size of sand particles found in various geographic locations, as well as the climatic factors of rainfall, temperature, humidity, wind, and storm frequency, the methods and materials used locally for dune stabilization may vary considerably (4).

American beach grass (Ammophila breviligulata), European beach grass (Ammophila arenaria), and Volga wild rye (Elymus gigantia) have been used successfully for dune stabilization in the Pacific Northwest (6). Sea oats (Uniola paniculata), which resembles beach grass, is used for dune control in the South and Southeast (7). European and American beach grass grow vigorously and produce rhizomes that develop buds at the nodes. These buds elongate and produce new plants or, if covered with sand, they develop long internodes and scale leaves until the surface is reached, whereupon the apex develops into a new leafy shoot (2). A recent survey in the Northeast showed almost no surviving stands of European beach grass along the coastal areas. Experimental plots showed that American beach grass is more vigorous and hardy in these areas (3). Establishment of grass through the use of seed for dune stabilization has been unsuccessful in most areas (5).

The purpose of this investigation was to determine the best and most economical methods for stabilizing dunes. Beach grass transplants and seedings of drought re-

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sistant grasses were evaluated. Various mulches were compared to determine their effectiveness in establishment of seeded grasses.

USE OF BEACH GRASS TRANSPLANTS FOR DUNE STABILIZATION

Various spacing methods of beach grass transplants were used to determine a rapid and economical method of revegetating shifting sand dunes. The space patterns were as follows:

Plot 1: Alternate 10-ft strips of beach grass and sand; beach grass planted on 18-in. centers.

Plot 2: Alternate 15-ft strips of beach grass and sand; beach grass planted on 18-in. centers.

Plot 3: Entire area planted to beach grass with a spacing 18 by 36 in.

Conventional plantings made on 18-in. centers require 19,360 transplants per acre. The planting pattern used in Plots 1 and 2 has often been used to reduce the excessive number of transplants needed. Machine planted beach grass with a spacing of 18 by 36 in., as in Plot 3, uses the same number of plants per acre as the alternate strip patterns of planting used in Plots 1 and 2.

In June 1962, 50- by 100-ft plots were established using these spacing and pattern systems. A modified Powell "42" transplanter, normally used for tobacco and cabbage, was employed. The beach grass was planted 4 to 5 culms per hill, 6 in. deep. All plots were then fertilized at the rate of 500 lb of 10-10-10 fertilizer per acre and top-dressed in July with urea at the rate of 45 lb of nitrogen per acre. By fall the number of culms had doubled and there was evidence of strong rhizome formation. In the spring of 1963, Plots 1 and 2 had a sand deposit of 5 to 7 in. above the original level and 5 to 7 in. of erosion in the bare strips between the plantings. Both plots had an erosion channel through one section of the plantings. The eroded areas were replanted in the spring. Plot 3 had no erosion but had accumulated 1 to 2 in. of sand.

In the summer of 1963, (Fig. 1), the plants from the beach grass rhizomes on Plot 3 had filled in the area satisfactorily for dune stabilization. In Plots 1 and 2, rhizomes were extending into the bare strips, but many were exposed and some were desiccated. As late as the fall of 1964, plots had not been filled in with beach grass. However, Plot 3 was a solid mass of beach grass.

A replication of this experiment, located closer to the top of a dune and on the windward side, was established in April 1963. During the following summer these plots were given an extra application of urea, equivalent to 45 lb of nitrogen per acre. The results observed in the summer of 1964 were the same in this experiment except that the plants produced more culms, some 20 to 30 per hill, and the rhizome development was better. The beach grass in the plot with the 18- by 36-in. spacing was excellent and had completely filled in the area by summer of 1964. Beach grass development in Plots 1 and 2 was excellent, but the bare areas were not vegetated.

A 3-acre planting of beach grass, with a 18- by 36-in. spacing, was made by machine across the windward side of a shifting dune on April 9, 1963. Fertilizer was added at the same rate as on the preceding plots, with an additional 100 lb of urea per acre. By fall the original 4 to 5 culms placed in each hill had increased to 20 to 30 culms, and rhizome development was excellent. In the spring of 1964, 10 to 12 in. of sand had been stilled by this planting. There was no scouring of beach grass plants. By summer the area was filled satisfactorily with plants that had developed from the rhizomes.

Plantings of beach grass made on Oct. 4, 1962, using the three patterns of planting, were badly scoured by spring of 1963, even though establishment of beach grass was excellent. On Oct. 9, 1963, an acre plot of beach grass was planted by machine next to the 3-acre plot that was planted on April 9, 1963. This plot was also well established but was badly scoured by the spring of 1964. Evidently, fall planting did not allow time for the beach grass to develop good root systems to hold the sand in place.

Several blowout areas between dunes were built up with sand to a height of 4 ft by the use of a picket-type snow fence. In the fall of 1962 two rows of a regular 4-ft

Figure 1. Beach grass spacing plots, second summer; machine planted in foreground completely filled, and 15- ft and 10-ft spaces in background remain bare.

Figure 2. Beach grass, machine planted on top of blowout, filled in by use of sand fence over winter; shown in July of second year.

Figure 3. Nursery of beach grass established in spring with single culms planted 4 by 18 in.; shown in July of second year.

snow fence ($\frac{3}{8}$- by $1\frac{1}{2}$-ft slats with 2-in. spaces and 4 double wires) were placed 30 ft apart at right angles to the prevailing wind. The first line of fence was set inward so that the top of the fence was at the same height as the sand in the dune. Several 10-ft spurs, 40 to 50 ft apart, were placed perpendicular to and on the inside of the two rows of snow fence to prevent lateral drift of sand. Steel and wood poles, $6\frac{1}{2}$ to 7 ft high, were spaced 10 ft apart in the fence lines and anchored with guy wires on both sides to strengthen the fence against the severe winds. By spring of 1963 the blowout area was filled with sand and a broad dune had developed. To provide protection and prevent the wind from scouring the sand, the top of the newly formed dune was transplanted to beach grass in the spring of 1963. The area was fertilized and topdressed using the same standard rates and by the fall of 1963 the grass establishment was very good. In July 1964, the top of the dune was in excellent condition (Fig. 2). On an adjacent area, similarly planted in October 1963, the beach grass plants were well established before winter. However, this area was badly eroded and the plants were scoured by the wind during the following winter. It is important to mention that the vast area in front of the blowout was seeded to grass in the spring of 1963, and by fall was fairly well covered. This helped to give some protection to the fenced area through the winter of 1963-1964.

The source of beach grass plants for transplanting has been from areas of naturally established grass. Clumps of beach grass were gathered at random with a spade and separated into bunches of 4 to 5 culms. Tops were sheared to facilitate machine planting. The disturbed area was then topdressed with urea at a rate of 100 lb per acre to stimulate regrowth of the beach grass. No damage was done to the area where the beach grass was removed.

If nursery grown material is not available, a tremendous number of plants can be grown in a small area if single culms of beach grass with spacing of 4 in. apart and 18 in. between rows are planted in the spring, and fertilized with 500 to 600 lb of 10-10-10 fertilizer per acre, and a month later topdressed with 100 lb urea per acre. Figure 3 shows a 200-sq ft plot planted with 560 culms as it looks in June of the second year with 3,360 culms. A single culm produced an average of 6 culms by fall. Fall plantings in a nursery could also be started.

VALUE OF MULCH IN ESTABLISHMENT OF DROUGHT RESISTANT PLANTS FROM SEEDS

On May 7, 1962, seeds of 11 different grasses and a legume were planted on the windward side of a dune, using a grain drill in which the seed box was partitioned so as to deposit each species in a separate row. Oats were used to increase the bulk of the seed. The single disc openers of the grain drill had a metal bar 2 in. wide welded around the inside of the disc to prevent burying the seed too deeply. During the seeding operation each planting unit was allowed to float freely over the sand. After planting, a 10-10-10 fertilizer was broadcast over the whole area at the rate of 500 lb per acre.

Mulches of resin, latex, asphalt compounds, sodium silicate, jute mesh, and hay were placed in duplicate 20- by 20-ft plots over the seeded area to determine their value in grass establishment on bare sand. Table 1 gives the rate of application and the evaluation of the mulches used as related to seedling emergence and survival.

Asphalt Emulsion and Asphalt Cutback

A smooth, uniform film was obtained on the seeded plots with undiluted asphalt compounds using 70 lb of pressure from a special spray gun. The film of both compounds was still in good condition when observed the next fall but had contracted and cracked considerably by the following spring. The sand level of the plot remained the same with no loss or accumulation.

Seedling emergence was very poor on both plots, probably due to the heavy film or a lack of moisture beneath the mulch. Plants that did emerge soon became bleached and died because of the increased surface temperatures caused by heat absorption of the blacktop. By spring 1963, there was no plant survival. In the spring of 1964, there was only a trace of asphalt mulch visible on the surface.

Elastomeric Polymer Emulsion

A thin pliable film of elastomeric polymer emulsion, diluted 1:5 with water, was applied with a hand sprayer over the seeded plots. By fall most of the film had deteriorated with about 5 percent of the emulsion remaining in a chunklike form. This plot was eroded to a depth of 3 to 4 in. by the following spring with no emulsion remaining.

Seedling emergence was very poor with the exception of a row of tall fescue and coastal panic grass in one plot. A visit to the plots in February 1963 showed loss of sand and exposure of the rows of seed that did not germinate. The cause of lack of germination was not determined. In the spring of 1964, these plots were bare and showed extensive erosion.

TABLE 1

INFLUENCE OF VARIOUS MULCHES ON GRASS SEEDLING EMERGENCE AND SURVIVAL

Mulch	Mulch Rates (per acre)	Plant Emergence,[a] 6-28-62	Plant Survival[a]	
			10-9-62	5-22-63
Asphalt emulsion[b]	200 gal	P	P	P
Asphalt cutback[b]	200 gal	P	P	N
Elastomeric polymer emulsion[c]	700 lb	P	P	P
Polyvinyl acetate copolymer[d] and ammonium sulfate	69 gal	-	-	-
	55 lb	E	E	G
Polyvinyl alcohol solution[d]	300 gal	G	G	G
Sodium silicate and ammonium sulfate	66 gal	-	-	-
	200 gal	E	E	G
Gelatin	1,000 lb	P	P	N
Hay	2,000 lb	P	P	N
Heavy jute mesh, ¾-in. opening	-	E	E	G
Control	-	E	E	G

[a]E = excellent, G = good, F = fair, P = poor, N = nothing. [b]Asphalt emulsion (agricultural mulch E. A. P. 2005) and cutback supplied by Esso Research and Engineering Co. [b]Soil set, Alco Oil and Chemical Corp. [c]Ludlow Textile Co. [d]Respectively, Gelva Emulsion T. S. 70 and Gelvatol 1-60, Shawinigan Resin Corp.

Polyvinyl Polymer Emulsion and Alcohol Solutions

The polyvinyl polymer emulsion, diluted 1:3 with water, was hand sprayed over a plot that was previously sprayed with a solution of ammonium sulfate. The polyvinyl alcohol solution was diluted 1:1½ and also hand sprayed. Both materials produced a thin crust on the surface that was still present in the fall. By the following spring both had deteriorated.

Seedling emergence was good to excellent, and grass establishment was good during the first summer. Observation the following spring showed good grass survival. Stilling of sand was accomplished with a 3 to 4-in. accumulation behind rows of established grasses. Erosion, 3 to 4 in. in depth, was evident where grasses failed to establish themselves.

Sodium Silicate

An excellent film was obtained by using a 2½ percent solution of sodium silicate on a seeded plot that had been previously sprayed with a solution of ammonium sulfate. Both solutions were hand sprayed. Observations in the fall showed that the crust had deteriorated.

Seedling emergence was very good. Growth was slightly superior to the grasses in the other plots, probably due to the extra nitrogen applied to help reduce the alkalinity of the sodium silicate solution. Grass growth was good the following spring. The level of sand accumulation and the depth of erosion were the same, 3 to 4 in. in depth, as in the polyvinyl polymer plots.

Gelatin

The mulch was produced by broadcasting gelatin uniformly over sand that had been previously moistened, and spraying with water to form a gelatin mass. The sun and desiccating winds dried and flaked the gelatin in 2 to 3 hours. By summer the mulch had deteriorated.

Seedling emergence was very poor. Evidently the concentration of gelatin affected seed germination. By spring, few scattered plants were present, and sand had been eroded 3 to 4 in. deep.

Hay

A lawn edger was used to anchor the hay mulch to a depth of 4 in. in rows 8 in. apart. This was done to prevent the wind from blowing the hay away and simulated the anchoring effect of a disc packer. The mulch withstood the strong winter winds and accumulated 3 to 4 in. of sand by spring.

Seedling emergence was extremely poor with only a few seedlings of oats showing. It was believed that anchoring the hay to a depth of 4 in. dried the sand to that depth and interfered with germination. Observations made in the spring showed a uniform cover of native beach grass seedlings which evidently originated from seed deposited in the hay mulch by wind blowing across nearby stands of beach grass. In 1964 this plot was in excellent condition and was accomplishing its purpose of sand stilling (Fig. 4).

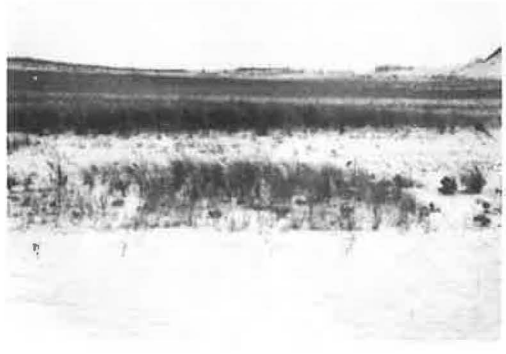

Figure 4. Hay mulch plot of 1962 with natural beach grass in July of second year.

Jute

A heavy jute mesh, 3-ft wide with ¾-in. openings, was anchored to the sand with 6-in. aluminum hooks. Spring observations showed that the jute mesh was still intact and had only slightly deteriorated.

Seedling emergence was fair to good on these plots. There was no loss of sand by wind erosion, but there was an

accumulation of about 3 in. of sand behind the rows of grasses that established themselves.

Control

The control plots that contained no mulch materials established grasses as well or better than some of the mulch plots, with the exception of the sodium silicate-sprayed plots. By spring this difference was no longer evident. The grasses on the check plots were good when observed in the spring, and sand accumulation and erosion was the same 3 to 4 in. as in the other plots.

Results

Under the climatic conditions in 1962 in the Provincetown area, it appears that the use of mulch for grass establishment was of no value. Grass was established as well on the plots with no mulch as it was on the best of the mulch plots. The sodium silicate plot produced slightly better grass, but this was evident only during the first summer, and was due, no doubt, to the extra nitrogen the grasses received from the ammonium sulfate. Moisture determinations made to a depth of 4 in. below the mulch on July 16, 1962, showed no significant differences in available water as compared to the control plot.

EVALUATION OF DROUGHT RESISTANT PLANTS FROM SEED

Table 2 gives an evaluation of the 12 species which were seeded and on which various mulches were applied. The rating system takes into account the number, distribution and, to a lesser degree, the vigor of the plants.

Results

Observations made on July 17, 1962, showed that germination was very good for most species with the exception of bulbous bluegrass and sericea lespedeza which did not germinate. Oats used with the seed to increase bulk for seeding germinated well, grew to a height of 6 to 7 in., and produced heads with several florets. Survival of seedlings by plant count was lost because of stake removal by summer visitors. There was some loss of grass from all plots because of the hot and dry summer. By fall weeping love grass, coastal panic grass and tall fescue looked most promising. Some of the wheatgrasses had excellent survival, but the plants showed little vigor and growth. This was also true in the second and third years. Tall fescue and coastal panic grass were excellent in the second and third years. Weeping love grass makes excellent growth in one summer, but it does not survive the winters. It should be mentioned that these plots were fertilized in 1963 with two applications of 100 lb of urea (45 percent nitrogen) per acre, and in 1964 with one application of 100 lb urea per acre.

TABLE 2

EVALUATION OF SPECIES ESTABLISHED ON SAND DUNES

Species	Rating[a]			
	July 17, 1962	Oct. 9, 1962	Feb. 6, 1963	May 22, 1963
Domestic ryegrass (Lolium spp.)	E	G	G	N
Pubescent wheatgrass (Agropyron trichophorum)	E	E	G	G
Bulbous bluegrass (Poa bulbosa)	N	N	N	N
Switch grass (Panicum virgatum)	E	G	G	G
Coastal panic grass (Panicum amarulum)	E	E	E	E
Weeping love grass (Eragrostis curvula)	E	E	E	N
Crested wheatgrass (Agropyron desertorum)	E	G	F	F
Sericea lespedeza (Lespedeza cuneata)	N	N	N	N
Tall fescue (Festuca arundinacea)	E	E	E	E
Siberian wheatgrass (Agropyron sibericum)	E	E	G	F
Streambank wheatgrass (Agropyron riparium)	E	E	G	G
Russian wild rye (Elymus junceus)	E	E	G	F

[a]E = excellent, G = good, F = fair, N = nothing.

Figure 5. Panicum amarulum planted from seed with a grain drill. Picture taken in July of the second year.

LARGE-SCALE PLANTINGS

Based on information from the test plots, acre-sized plots were established on April 1, 1963, using the most promising species mentioned previously, as well as beach grass seed gathered from plants in the surrounding area. Three days later a wind storm with velocities up to 75 mph blew out all the plots. On May 23, 1963, another seeding was made using 50 lb of oats per acre with each grass species. Since no more beach grass seed was available, hard fescue (Festuca durar) and switch grass (Panicum virgatum) were substituted. Seeding rates in pounds per acre were as follows: tall fescue, 42; hard fescue, 30; coastal panic grass, 20; switch grass, 20; and weeping love grass, $2\frac{1}{2}$.

At seeding time, 220 lb of 10-10-10 fertilizer per acre was drilled in with the seed. The area was topdressed with 100 lb of urea on June 8, 1963, and with 100 lb of 10-10-10 on July 1, 1963.

All grass seeds germinated well and survival was good throughout the summer (Fig. 5). The grasses made only a few inches of growth, with the exception of weeping love grass which grew 7 to 8 in. tall. By fall some of the plants were producing seed stalks. All species survived the winter except weeping love grass. In the spring of 1964, all plots had withstood the severe winter scouring and had accumulated some sand. Adjacent areas with no vegetation lost from 8 to 12 in. of sand. In May, the whole area was topdressed with 100 lb of urea per acre. All plots, with the exception of the hard fescue, looked good in July 1964.

On Sept. 28, 1962, 1-acre plots of winter barley and rye were seeded at the rate of 100 lb per acre with a grain drill using about 500 lb of a 10-10-10 fertilizer per acre at the time of seeding. On Oct. 9, 1962, both plots were in good condition and were topdressed with 80 lb of urea per acre. In February 1963, the rye and barley plants were slightly desiccated and sandblasted, but the seeded area prevented the sand from moving. Plants brought into the laboratory survived and grew, but the plants on the dune area were further sandblasted and killed by spring. A sand stilling job was accomplished, but the cereal grains did not survive the sandblasting.

In 1962 and 1963, vegetation was successfully established from seedings of coastal panic grass, tall fescue and weeping love grass on the windward side of dunes. Hard fescue and switch grass did not make as good cover as the others.

Planting seed of drought resistant grasses with a grain drill 2 in. deep is a rapid and economical method for the Provincetown area. Early spring planting, about the 1st of April, should be avoided because of possible loss of seed from severe wind storms. Plantings should not be made during the summer because of poor conditions for germination and growth. Seeding at the rates indicated appears to produce a satisfactory cover. Not more than 250 lb of 10-10-10 fertilizer per acre should be applied at planting because of possible fertilizer burn. The grasses should be topdressed with 300 lb of 10-10-10 a month later, followed by a topdressing of urea (45 percent N) at the rate of 80 to 100 lb per acre during the summer. In the spring of the second year, a topdressing of 500 lb of 10-10-10 fertilizer per acre should be applied, plus 80 to 100 lb of urea a month later if necessary. Since the sands are extremely low in fertility, additional fertilizer might be beneficial during the fall of the year. If blowout areas are to be built up with snow fences, it is suggested that seeding of grasses on the windward side of the dune be delayed until the blowout areas are filled to the desired height.

If an area is to be used as a play area and the sand movement is to be controlled without permanent vegetation, rye or winter barley can be planted in early September and fertilized with 500 lb of 10-10-10 per acre. By spring most of the plants will be

desiccated and sandblasted, but the roots will prevent most of the sand from moving. The dried vegetation should not interfere with play the following summer.

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