CETA 77-4

Planting Guidelines for Dune Creation and Stabilization

by

Paul L. Knutson

COASTAL ENGINEERING TECHNICAL AID NO. 77-4
SEPTEMBER 1977

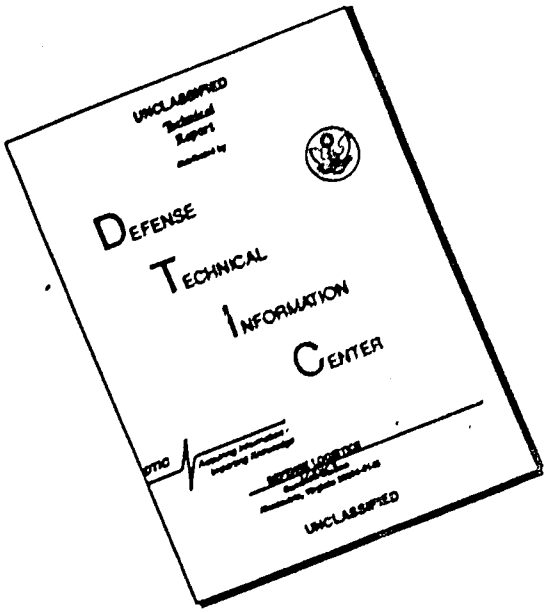
Approved for public release;
distribution unlimited.

U. S. ARMY, CORPS OF ENGINEERS

COASTAL ENGINEERING RESEARCH CENTER

Kingman Building
Fort Belvoir, Va. 22060

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

U.S. ARMY COASTAL ENGINEERING RESEARCH CENTER

Kingman Building

Fort Belvoir, Virginia 22060

28 October 1977

ERRATA to CETA 77-4

Planting Guidelines for Dune Creation and Stabilization

September 1977

The following changes should be made:

Page 20 - (Figure B-1). Reverse captions for illustrations b and c; b should read "Ligule - American beachgrass x 2;" c should read "Ligule - European beachgrass x 2."

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CERC-CETA-77-4	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): PLANTING GUIDELINES FOR DUNE CREATION AND STABILIZATION	5. TYPE OF REPORT & PERIOD COVERED: Coastal Engineering Technical Aid rept.
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Paul L. Knutson	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Department of the Army, Coastal Engineering Research Center (CERRE-CE), Kingman Building, Fort Belvoir, Virginia 22060	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: G31530
11. CONTROLLING OFFICE NAME AND ADDRESS: Department of the Army, Coastal Engineering Research Center, Kingman Building, Fort Belvoir, Virginia 22060	12. REPORT DATE: Sep[illegible]77
	13. NUMBER OF PAGES: 26
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 27p.	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Beach grasses
Dune creation
Erosion
Planting guidelines
Stabilization

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as a natural barrier to the inland penetration of waves and storm surges. Techniques are available for the efficient propagation of beach grass for this purpose. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements for planting projects.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

037050. 2.

PREFACE

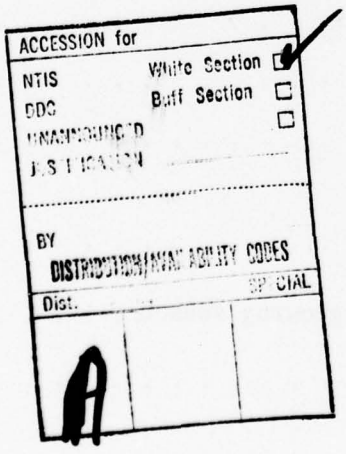
This report is a guideline for making plantings for dune creation and stabilization in the coastal zone. The guideline is intended to augment information in Chapter 6 of the Shore Protection Manual (SPM), (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975).

The report was prepared by Paul L. Knutson, Coastal Ecology Branch, under the general supervision of R.M. Yancey. Illustrations were prepared by the author and L. Martin.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director



CONTENTS

TABLES

CONTENTS--Continued

FIGURES

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

PLANTING GUIDELINES FOR DUNE CREATION AND STABILIZATION

by
Paul L. Knutson

I. INTRODUCTION

Foredunes function as reservoirs of sand that nourish eroding beaches during high water, and as levees that delay the inland penetration of waves and storm surges (see App. A for a glossary of terms). These dunes are usually naturally created and maintained by the action of beach grasses which trap and hold blowing sand. Erosion occurs if this vegetation is damaged by drought, disease, overgrazing, traffic, or waves during severe storms. Damaged dune systems can be restored by planting beach grasses.

II. APPLICATIONS

1. General.

Beach grasses may be used to form dunes on any backshore that is about 300 feet (91 meters) wide and has an adequate supply of moving sand particles. (In these areas sand will deposit around the beach grasses, bits of debris, and other obstructions.) However, in most cases, beach-grass planting is used to restore damaged dunes. There are three types of dune damage that may occur: (a) Wind erosion often occurs on the seaward face of foredunes where vegetation has been destroyed. As erosion continues, "bowl-shaped" depressions called *blowouts* are formed (Fig. 1). (b) During severe storms, weakened parts of the dune line may be breached, forming "washover channels." These channels may flood p[illegible]ically (Fig. 2). (c) In some areas, wind and wave erosion level[illegible]riginal dune field, leaving a "barren" backshore (Fig. 3).

2. [illegible]ific.

a. Stabilizing Blowouts. If wind erosion occurs on the seaward face of a foredune, the entire disturbed area should be planted.

b. Closing Washover Channels. Beach grasses will not survive in washover channels subject to periodic flooding and wave action. To prepare these areas for planting, erect six parallel rows of 4-foot-high (1.2 meters) picket snow (sand) fencing, spaced 10 feet (3 meters) apart in a 50-foot (15 meters) width, 1 year before planting. After the spaces between fences have filled with sand, the area is ready for planting. A dune 2 to 3 feet (0.6 to 0.9 meter) high may be formed with construction equipment to avoid delay; however, this method costs more. This initial dune should be built 50 feet landward of the estimated dune line to allow for dune widening. A final base width of 100 feet (30 meters) or more is desirable. About 4 to 5 years after the initial planting, another 50-foot-wide strip may be added immediately seaward of the existing vegetation if the 100-foot width has not developed naturally. Dunes built

Figure 1. Two blowouts on face of foredune.

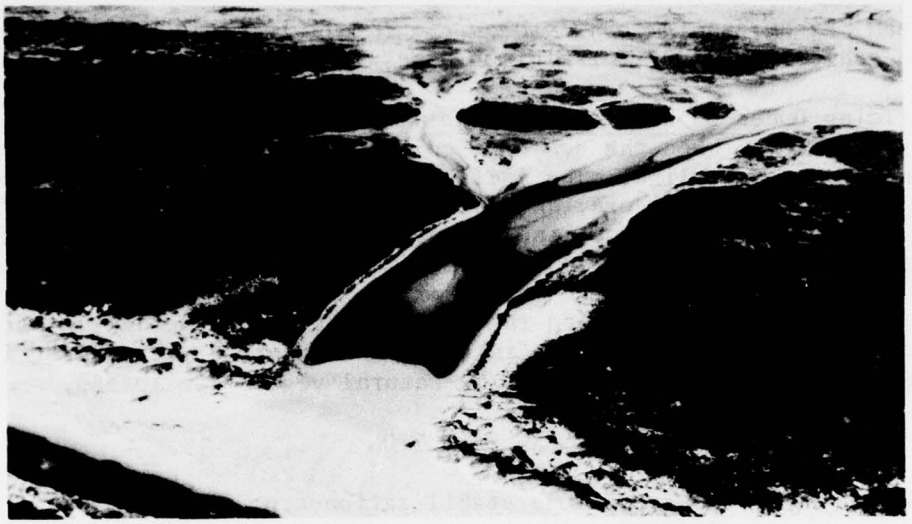


Figure 2. Washover channel, subject to flooding during storms and high water.

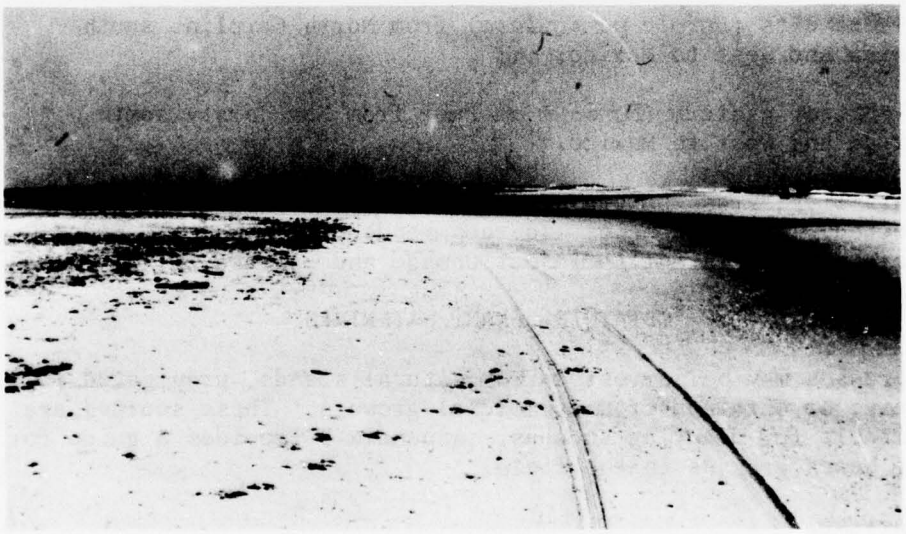


Figure 3. Barren backshore, absent of vegetation and sand dunes.

with American beachgrass (*Ammophila breviligulata*) will seldom require widening to achieve the 100-foot-minimum base width.

c. Building Dunes on Barren Backshores. Foredune restoration is most likely to succeed when the new dune coincides with the natural vegetation line or foredune line. The initial planting should be a strip 50 feet wide, parallel to the shore, and 50 feet landward of this line. If a natural vegetation or foredune line is not evident, restoration should begin at least 250 to 300 feet (76 to 91 meters) inland from the high water line. Where beach recession is occurring, the dune location should be determined from the average erosion rate and the desired dune life. Another 50-foot-wide strip may be added immediately seaward 4 to 5 years later if a base of 100 feet has not been achieved by natural vegetative spread.

III. PLANT SELECTION

The grasses recommended for dune stabilization are:

(a) American beachgrass (*Ammophila breviligulata*) in Maine south to northern North Carolina, the Great Lakes, Oregon, Washington, and California;

(b) European beachgrass (*Ammophila arenaria*) in Oregon, Washington, and California;

(c) Sea oats (*Uniola paniculata*) from North Carolina south to Florida and west to Mexico; and

(d) Bitter panicum (*Panicum amarum*) from New Jersey south to Florida and west to Mexico.

From this list, grass or grasses recommended for a geographical area can be selected. If two species are recommended, plant both. Mixed plantings are more resistant to insect damage and disease.

IV. OBTAINING PLANT MATERIALS

Beach grasses may be harvested from natural stands, propagated in a field nursery, or obtained from commercial growers. These sources are equally suitable for planting success. Appendix B provides a guide for identifying beach grasses in the field.

1. Wild Harvest.

Plants may be obtained from natural stands. However, State laws should be checked. It is illegal in some States to harvest sea oats. Care must be taken to assure that natural dunes are not damaged by harvesting. Plants should not be taken from foredunes or in other areas where erosion is a potential problem. In general, harvesting can be safely conducted only in protected areas behind the first dune line. Beach grasses thrive where sand moves. In protected areas where sand

movement is low, plant growth is usually poor. The number of harvestable plants may be increased by fertilizing the area (see Sec. VII) 1 year before harvesting. (Mature stands of sea oats may not respond to fertilization.) During harvesting, part of each clump should be undisturbed to allow regeneration of the stand. If future harvesting is planned, the area should be refertilized.

a. American and European Beachgrasses. Clumps may be pulled or dug from the sand. Shake the clumps free of sand, separate into transplants with about three stems (culms) each. All transplants will not have roots, though a basal node should be present from which roots will develop after planting. Plants may be trimmed to a height of 15 to 20 inches (38 to 51 centimeters) to facilitate mechanical planting.

b. Sea Oats. Since the nodes are usually buried, transplants must be dug carefully with a shovel to dislodge the clump intact. Once dislodged, single-stem transplants can be separated from the clump, cleaned of dead material, and trimmed if necessary to facilitate mechanical planting.

c. Bitter Panicum. Single-stem transplants can be pulled from the sand by hand. Roots are not necessary, and culms can be broken off at ground level. Culms 1.5 to 3 feet (0.5 to 0.9 meter) long are preferred over shorter ones; those under 10 inches (25 centimeters) long are unsatisfactory. Stems over 3 feet long should be broken in half, and both halves planted. Again, plants to be used for mechanical planting should be trimmed to 15- to 20-inch lengths.

2. Field Nursery.

If adequate wild or commercial stock is not available, a nursery should be established. A nursery ensures a supply of easy to handle, uniform-size transplants. In one growing season, a 1-acre (4.047 square meters) nursery will yield approximately:

(a) 25,000 to 50,000 three-stem transplants of American beachgrass;

(b) 50,000 to 75,000 three-stem transplants of European beachgrass; or

(c) 50,000 to 75,000 single-stem transplants of bitter panicum on the Atlantic coast and 75,000 to 100,000 on the gulf coast.

In two growing seasons, a 1-acre nursery will yield approximately 50,000 to 75,000 single-stem transplants of sea oats on the Atlantic coast or 75,000 to 100,000 on the gulf coast.

Specifications for a nursery are discussed in Appendix C.

3. Commercial Growers.

A U.S. Department of Agriculture Soil Conservation Service list of commercial distributors of beach grasses is in Appendix D. Commercial stock

can eliminate the need for wild harvesting or field nurseries and is normally delivered ready to plant.

V. STORAGE OF PLANTS

Most plants may be stored several weeks if their bases are wrapped with wet burlap, covered with moist sand, or placed in containers with 1 to 2 inches (25 to 50 millimeters) of freshwater. Survival of sea oats is reduced if stored more than 3 to 4 days. To reduce weight during transport, the roots and basal nodes may be dipped in a clay slurry, and the plants bundled and wrapped in reinforced paper. Plants may be kept longer if refrigerated. Plants dug while dormant (winter) and held in cold storage 1° to 3° Celsius may be used in late spring plantings.

VI. PLANTING

1. Planting Methods.

Transplanting may be by hand or with a tobacco or strawberry planter and a five-man crew. Hand planting is nearly as efficient as machine planting in moist sand. In dry sand, loose particles continually backfill the hole, making hand planting less efficient than mechanical planting. When planting by hand, holes should be staggered to allow maximum erosion control. Holes may be opened with a dibble, spud bar, or tilling spade. When using a mechanical planter, rows of holes should be oriented parallel to the shorelines. Soil must be packed firmly around all plants to eliminate airspaces, prevent blowouts, and hold moisture.

2. Plant Spacing.

Transplants of all recommended species should be planted on 18-inch (46 centimeters) centers at eroding sites and 24-inch (61 centimeters) centers at noneroding sites, or approximately 19,000 transplants per acre (4.7 transplants per square meter) and 11,000 transplants per acre (2.7 transplants per square meter), respectively.

3. Planting Season.

Table 1 provides a general guide to planting season.

VII. POSTPLANTING CARE

1. Fertilization.

All plantings should be fertilized during the first growing season to encourage rapid spread. Table 2 is a recommended fertilization schedule for the first growing season.

Only American beachgrass should be routinely fertilized the second growing season with 50 pounds per acre (5.6 grams per square meter) of 3-1-0 fertilizer in April and again in September. Other species should

Table 1. Guide to planting season.

Planting season	Species			
	Beach grass			
	American	European	Panicum	Sea oats
Late fall to early winter	Yes[1]	Yes	Yes	No
Mid-winter	Yes[1]	Yes	Optimum	Optimum
Late winter to early spring	Optimum[1]	Optimum	Optimum	Yes
Early spring to mid-spring	Yes	Yes	Yes	No

[1]Season not recommended for Great Lakes.

Table 2. Fertilization schedule for the first growing season.

Fertilizer (quick release)	Species			
	Beach grass			
	American	European	Panicum	Sea oats
Composition (N-P-K)[1]	3-1-0[2]	7-0-0	2-1-1	2-1-1
Application rate (lb/acre/yr)	200	40	240	240
Application periods (equal applications in months indicated)	Mar. May July Sept.	Apr.	Apr. June Aug.	Apr. June Aug.

[1]N-P-K = nitrogen-phosphorus-potassium.
[2]3-1-1 in Great Lakes.

be fertilized if overall growth or survival is poor or if plants do not appear healthy. In general, only areas of poor plant growth will require fertilization. During the third growing season, fertilizer can be applied as required to encourage growth. However, sea oats is not responsive to fertilizer after the second season.

2. Replanting.

Areas of total plant mortality or localized areas with less than 10-percent survival must be replanted. A planting with 20-percent survival (50-percent for European beachgrass in the Pacific Northwest) should require only localized replanting if reasonably uniform. Ideally, a winter planting with poor survival should be replanted as soon as possible--late spring or summer if soil conditions permit, or not later than the following winter.

VIII. LABOR REQUIREMENTS

The approximate number of man-hours required to harvest, process, and plant 1 acre (50- by 875-foot plot) is given in Table 3.

Table 3. Labor required for planting 1 acre.

Operation	Species			
	Beach grass (man-hour/acre)			Sea oats (man-hour/acre)
	American	European	Panicum	
Harvesting and processing				
18-inch spacing	40	40	55	110
24-inch spacing	25	25	30	60
Planting (mechanical)[1]				
18-inch spacing	45	45	45	45
24-inch spacing	25	25	25	25
Total labor				
18-inch spacing	85	85	100	155
24-inch spacing	50	50	55	85

[1]If hand planting, add 20 percent.

BIBLIOGRAPHY

DAHL, C.E., FALL, G.A., and APPAN, S.G., "Construction and Stabilization of Coastal Foredunes with Vegetation: Padre Island, Texas," MP 9-75, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Sept. 1975.

DAVIS, H.H., "Dune Formation and Stabilization by Vegetation and Plantings," TM-101, U.S. Army, Corps of Engineers, Beach Erosion Board, Washington, D.C., Oct. 1957.

GAGE, B.O., "Experimental Dunes of the Texas Coast," MP 1-70, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Washington, D.C., Jan. 1970.

HALL, V.L., and LUDWIG, J.D., "Evaluation of Potential Use of Vegetation for Erosion Abatement Along the Great Lakes Shoreline," MP 7-75, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., June 1975.

HITCHCOCK, A.S., *Manual of the Grasses of the United States*, 2d ed., revised by Agnes Chase, 2 Vols., Dover, New York, 1971.

JAGSCHITZ, J.A., and WAKEFIELD, R.C., "How to Build and Save Beaches and Dunes," Marine Leaflet Series No. 4, Agricultural Experiment Station Bulletin 408, University of Rhode Island, Kingston, R.I., Oct. 1971.

SENECA, E.D., WOODHOUSE, W.W., Jr., and BROOME, S.W., "Dune Stabilization with Panicum amarum Along the North Carolina Coast," MR 76-3, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Feb. 1976.

WOODHOUSE, W.W., Jr., and HANES, R.E., "Dune Stabilization with Vegetation on the Outer Banks of North Carolina," TM-22, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Washington, D.C., Aug. 1967.

WOODHOUSE, W.W., Jr., SENECA, E.D., and BROOME, S.W., "Ten Years of Development of Man-Initiated Coastal Barrier Dunes in North Carolina," Bulletin 453, Agricultural Experiment Station, North Carolina University at Raleigh, N.C., Dec. 1976.

APPENDIX A

GLOSSARY

BACKSHORE - That zone of the shore or beach lying between the FORESHORE and the coastline and acted upon by waves only during severe storms, especially when combined with exceptionally high water.

BASAL NODE - The lowest NODE on the stem. The intersection of roots and STEMS.

CULM - STEM of grasses, usually hollow except at the swollen NODES.

FOREDUNE - The front dune immediately behind the BACKSHORE.

FORESHORE - The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

NODE - Joint of a STEM where a leaf is borne or may be borne. Buds are also commonly borne at the node.

RHIZOME - Underground stem or rootstock, with scales at the NODES. Forms buds at the NODES that may, under proper stimulus, develop into leafy SHOOTS. Roots also develop from the NODES. New SHOOTS are usually produced from the tip of the RHIZOME.

SHOOT - Collective term applied to the STEM and leaves, or any growing branch or twig.

STEM - Main axis of a plant, leaf-bearing and flower-bearing as distinguished from the root-bearing axis.

TRANSPLANT - SHOOT or CULM removed from one location and replanted in another.

APPENDIX B

IDENTIFYING BEACH GRASSES

Tables and figures summarize the physical characteristics of American and European beachgrasses (Table B-1, Fig. B-1), sea oats (Table B-2, Fig. B-2), and bitter panicum (Table B-3, Fig. B-3).

Table B-1. Characteristics of American and European beachgrasses.

Category	Characteristics
Growth habit	Perennial grasses grow in tufts; base of plant usually buried in sand (Fig. B-1,e).
Seed head (inflorescence)	Seed heads nearly cylindrical but slightly thicker in the middle, tapering at the ends; 4 to 12 inches (10 to 30 centimeters) long and 1/2 to 3/4 inch (1.2 to 1.8 centimeters) thick; pale yellow in color (Fig. B-1,a).
Seeds (spikelets)	Seeds are pointed upward, closely pressed against a central stem; seed 3/8 inch (1 centimeter) long (Fig. B-1,d).
Stems (culms)	Stems erect and rigid; base of stem clothed in numerous overlapping sheaths; new stems arise from horizontal branching rootstock (rhizomes) of parent plant; stems 2 to 4 feet (0.6 to 1.2 meters) high.
Leaves	Leaves arise from the stem with greater frequency near the base; leaves have 10 to 12 veins; veins are more distinct on inside (facing stem); leaves are rolled (involuted) to a pointed tip and are up to 2 feet (60 centimeters) long; ligules (Figs. B-1,b and c) are about 1 inch (25 centimeters) long in European beachgrass but only 1/10 inch (2.5 millimeters) long in American beachgrass[1].

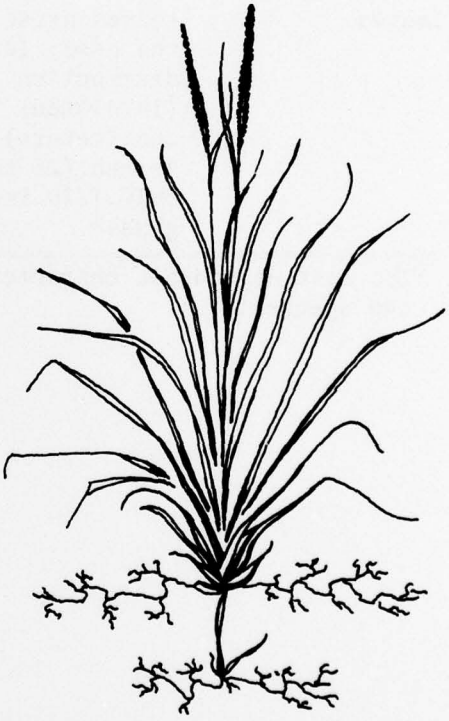
[1]The most dependable characteristic for distinguishing between these two species.

a. Seed head (inflorescence) x 1/3

b. Ligule - European beachgrass x 2

c. Ligule - American beachgrass x 2

d. Seed (spikelet) x 4



e. Growth habit x 1/15

Figure B-1. American and European beachgrasses.

Table B-2. Characteristics of sea oats.

Category	Characteristics
Growth habit	Perennial grass growing in large clumps more than 1 foot in diameter; base of plant typically buried in sand (Fig. B-2,c).
Seed head	Seed head is large and distinctive (Fig. B-2,a); 10 to 15 inches long and 3 to 5 inches (8 to 13 centimeters) wide; branched; drooping; yellow colored.
Seed (spikelets)	Seed in discrete groups of 10 to 21; each group is flat and oval, 1/4 to 1/2 inch (0.6 to 1.3 centimeters) wide and 3/4 to 1 inch (1.8 to 2.5 centimeters) long (Fig. B-2,b).
Stems (culms)	Stems from bunches attached to horizontal rootstock (rhizomes); erect and rigid 3 to 8 feet (0.9 to 2.4 meters) in height.
Leaves	Most leaves arise from the base of the plant, densely overlapping, and with fewer leaves along the stem; leaves are flat at base becoming more rolled (involute) near the ends; leaves about 1/4 inch (0.6 centimeter) wide, gradually narrowing into a long slender tip; leaves up to 3 feet (0.9 meter) in length; the tips of drier leaves are zigzagged, wavy, or curled in appearance (Fig. B-2, c).

a. Seed head (inflorescence) x 1/3

b. Seed (spikelet) x 2

c. Growth habit x 1/10

Figure B-2. Sea oats.

Table B-3. Characteristics of bitter panicum.

Category	Characteristics
Growth habit	Perennial grass growing in bunches; few horizontal branching rootstocks (rhizomes); fronted, whitish, or waxy in appearance (glaucous).
Seed head	Long and slender; roughly cylindrical; length 1/4 to 1/3 the height of plant and usually 1 inch (2.5 centimeters) or less wide (Fig. B-3,a).
Seed (spikelets)	Individual seeds are closely pressed against a central stem (rachis); seeds plump and less than 1/4 inch (0.6 centimeter) in length (Fig. B-3,b).
Stems (culms)	Stems arise singly (Fig. B-3,c) from underground joints (nodes); erect and rigid; typically 1.5 to 3 feet (0.5 to 0.9 meter) in length, occasionally to 7 feet (2.1 meters).
Leaves	Arising at regular intervals along the entire length of the stem; leaves broad, about 1/2 inch (1.2 centimeters) wide near base; leaves rounded (involute) near tips; much of leaf becomes twisted with age and drying.

a. Seed head (inflorescence) x 1

b. Seed (spikelet) x 8

c. Growth habit x 1/10

Figure B-3. Bitter panicum.

APPENDIX C

NURSERY SPECIFICATIONS

1. Site.

The nursery should be in a flat area either away from the beach, or leeward of an established dune line. A mature, sandy grassland may also be used, but should be graded to remove all vegetation 6 inches (15 centimeters) below the original surface, or fumigated well in advance of planting. Periodic weeding after planting is necessary.

2. Planting.

The plants should be arranged by species for easy harvesting. Use planting techniques discussed in Section VI. Spacing should be about 2 feet between hills and 3 feet between rows to allow mechanical cultivation.

3. Fertilization.

Only 1 year is required to produce a crop of American beachgrass, European beachgrass, or bitter panicum with fertilization. Sea oats crop production is variable and prime transplants typically come from 2-year-old stands. Yields per acre in field nurseries are in Section IV. The fertilization schedule recommended for the first growing season (Sec. VII; Table 2) is also appropriate for nurseries.

APPENDIX D

COMMERCIAL DISTRIBUTORS

The following is a list of known commercial distributors of beach grasses compiled by the U.S. Department of Agriculture, Soil Conservation Service.

1. American Beachgrass.

Allen DeVries
14835 Barry
Holland, Michigan 49423

Bar-Don Nursery
2611 Lockmoe Drive
Raleigh, North Carolina 27608

Church's Greenhouse and Nursery
Old Shore Road
Erma Road, #1
Cape May, New Jersey 08204

Coastal Stabilization Nursery
Box 65
New Bern, North Carolina 28560

Jackson Seed Company
East 8803 Sprague Avenue
Spokane, Washington 99206

Manistee Soil Conservation District
P.O. Box 275
Onekama, Michigan 49675

Mason-Lake Soil Conservation Districts
102 East 5th Street
Scottsville, Michigan 49454

Moores Sod Farm
P.O. Box 376
Berlin, Maryland 21811

Muskegon Soil Conservation District
Federal Building, Room 207
Muskegon, Michigan 49443

R & R Beachgrass
Box 33-R, D.I.
Lewes, Delaware 19958

Van Pine Inc.
Route #1
West Olive, Michigan 49460

D. M. Bryan
Route 2
Garner, North Carolina 27529

2. European Beachgrass.

Wilbur Ternyik
921 Rhododendron
Florence, Oregon 97439

3. Bitter Panicum.

D. M. Bryan
Route 2
Garner, North Carolina 27529

Horticultural Systems Inc.
P.O. Box 3
Brandenton, Florida 33506

4. Sea Oats.

Seacoast Plant Nursery
c/o Karl Graetz
Rt. 1, Box 874
Morehead City, North Carolina 28557

Horticultural Systems Inc.
P.O. Box 3
Brandenton, Florida 33506

Knutson, Paul L.
Planting guidelines for dune creation and stabilization / by Paul L. Knutson. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
26 p. : ill. (Coastal engineering technical aid - U.S. Coastal Engineering Research Center ; CETA 77-4)
Bibliography: p. 15.
Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as natural barriers to the inland penetration of waves and storm surges. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements.
1. Sand dune stabilization. 2. Erosion control. 3. Grasses. I. Title. II. Series: U.S. Coastal Engineering Research Center. Coastal engineering technical aid. CETA 77-4.

TC203 .U581ta no. 77-4 627

Knutson, Paul L.
Planting guidelines for dune creation and stabilization / by Paul L. Knutson. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
26 p. : ill. (Coastal engineering technical aid - U.S. Coastal Engineering Research Center ; CETA 77-4)
Bibliography: p. 15.
Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as natural barriers to the inland penetration of waves and storm surges. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements.
1. Sand dune stabilization. 2. Erosion control. 3. Grasses. I. Title. II. Series: U.S. Coastal Engineering Research Center. Coastal engineering technical aid. CETA 77-4.

TC203 .U581ta no. 77-4 627

Knutson, Paul L.
Planting guidelines for dune creation and stabilization / by Paul L. Knutson. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
26 p. : ill. (Coastal engineering technical aid - U.S. Coastal Engineering Research Center ; CETA 77-4)
Bibliography: p. 15.
Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as natural barriers to the inland penetration of waves and storm surges. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements.
1. Sand dune stabilization. 2. Erosion control. 3. Grasses. I. Title. II. Series: U.S. Coastal Engineering Research Center. Coastal engineering technical aid. CETA 77-4.

TC203 .U581ta no. 77-4 627

Knutson, Paul L.
Planting guidelines for dune creation and stabilization / by Paul L. Knutson. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
26 p. : ill. (Coastal engineering technical aid - U.S. Coastal Engineering Research Center ; CETA 77-4)
Bibliography: p. 15.
Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as natural barriers to the inland penetration of waves and storm surges. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements.
1. Sand dune stabilization. 2. Erosion control. 3. Grasses. I. Title. II. Series: U.S. Coastal Engineering Research Center. Coastal engineering technical aid. CETA 77-4.

TC203 .U581ta no. 77-4 627

Knutson, Paul L.
Planting guidelines for dune creation and stabilization / by Paul L. Knutson. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
26 p. : ill. (Coastal engineering technical aid - U.S. Coastal Engineering Research Center ; CETA 77-4)
Bibliography: p. 15.
Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as natural barriers to the inland penetration of waves and storm surges. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements.
1. Sand dune stabilization. 2. Erosion control. 3. Grasses. I. Title. II. Series: U.S. Coastal Engineering Research Center. Coastal engineering technical aid. CETA 77-4.

TC203 .U581ta no. 77-4 627

Knutson, Paul L.
Planting guidelines for dune creation and stabilization / by Paul L. Knutson. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
26 p. : ill. (Coastal engineering technical aid - U.S. Coastal Engineering Research Center ; CETA 77-4)
Bibliography: p. 15.
Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as natural barriers to the inland penetration of waves and storm surges. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements.
1. Sand dune stabilization. 2. Erosion control. 3. Grasses. I. Title. II. Series: U.S. Coastal Engineering Research Center. Coastal engineering technical aid. *CETA 77-4.*

TC203 .U581ta no. 77-4 627

Knutson, Paul L.
Planting guidelines for dune creation and stabilization / by Paul L. Knutson. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
26 p. : ill. (Coastal engineering technical aid - U.S. Coastal Engineering Research Center ; CETA 77-4)
Bibliography: p. 15.
Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as natural barriers to the inland penetration of waves and storm surges. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements.
1. Sand dune stabilization. 2. Erosion control. 3. Grasses. I. Title. II. Series: U.S. Coastal Engineering Research Center. Coastal engineering technical aid. CETA 77-4.

TC203 .U581ta no. 77-4 627

Knutson, Paul L.
Planting guidelines for dune creation and stabilization / by Paul L. Knutson. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
26 p. : ill. (Coastal engineering technical aid - U.S. Coastal Engineering Research Center ; CETA 77-4)
Bibliography: p. 15.
Beach grasses have been used successfully in many coastal projects to form and stabilize dune systems as natural barriers to the inland penetration of waves and storm surges. This report provides guidelines for (a) selecting plants and planting methods; (b) obtaining plants; (c) storing, planting, and maintaining plants; and (d) estimating labor requirements.
1. Sand dune stabilization. 2. Erosion control. 3. Grasses. I. Title. II. Series: U.S. Coastal Engineering Research Center. Coastal engineering technical aid. CETA 77-4.

TC203 .U581ta no. 77-4 627