AN ABSTRACT OF THE THESIS OF

Diantha Louise Green  for the  M. S.  in  Plant Ecology
(Name)  (Degree)  (Major)

Date thesis is presented  April 19, 1965

Title Developmental history of European beachgrass (Ammophila arenaria (L.) Link) plantings on the Oregon coastal sand dunes.

Abstract approved  Signature redacted for privacy.
(Major Professor)

A study of Ammophila arenaria (L.) Link, (European beachgrass) plantations was carried out on sand dunes along the Oregon coast to observe the vegetation changes which occur over a period of years.

Control of moving sand has been important on a world-wide basis for many years. In Oregon this problem has been the cause of concern since the 1930's. Ammophila is well adapted to the extreme environment of a coastal area and it is most vigorous in areas of drifting sand. It is a coarse, perennial grass used extensively in planting of sand dunes for stabilization. Ammophila is the primary species used in the Oregon plantation work.

Transplanting of the grass clones is the most frequently used method of planting on the dunes. Clones are planted with varying density and number of culms per hill according to the direction and degree of the slope. The planting is carried out between November and April when weather is cool and wet. To insure permanent
stabilization, secondary woody species are planted in the established Ammophila. The species used are Cytisus scoparius (Scotchbroom) and Pinus contorta (Lodgepole or shorepine). Cytisus is planted before or concurrently with the Pinus to provide protection for the Pinus.

Thirteen consecutive years of plantations were located and studied south of Florence, Oregon, where planting has been in progress since 1949. A 25 foot square plot was located in a uniform and typical area within the plantation. The plot was divided into five foot square quadrats with three foot square quadrats placed within each of these. Data included height, cover, diameter of clumps and density of Ammophila; height, cover and density of Pinus and Cytisus; cover of litter and Mnium sp. (moss); and frequency of the native species present in the plots. An analysis of sand determined the pH, total nitrogen and organic matter present.

The plantations varied in overall appearance for the 13 years. Ammophila showed a definite change from the clumped growth form observed in the first years of growth after planting to solitary shoots present in the oldest plots observed. Pinus and Cytisus showed a varied appearance throughout the plots with a general increase in height and cover. Density varied with the degree of success of the plantings. Native species were present and the frequencies varied with plantation age and location. The soil analysis proved a definite
decrease in pH with age of the plantation.

The oldest plot observed showed numerous native species including Picea sitchensis (Sitka Spruce). In time the areas now being planted will develop a typical native vegetation without any of the original planted species present.
DEVELOPMENTAL HISTORY OF EUROPEAN BEACHGRASS
(AMMOPHILA ARENARIA (L.) LINK) PLANTINGS
ON THE OREGON COASTAL SAND DUNES

by

DIANTHA LOUISE GREEN

A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1965
ACKNOWLEDGEMENT

I wish to express my appreciation to all those who gave guidance and encouragement to me while involved in this study. I am indebted to Alfred M. Wiedemann, Department of Botany, Oregon State University, for his help in the field work and in many other ways. The willing guidance and direction of Dr. W. W. Chilcote, Professor of Botany, Oregon State University, is greatly appreciated.

The assistance of the United States Forest Service and the Bureau of Land Management in making their records available for my use deserves mention.

Finally, I wish to express thanks to my parents, Mr. and Mrs. W. H. Green, for their constant encouragement and support.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>4</td>
</tr>
<tr>
<td>History of Planting Methods</td>
<td>4</td>
</tr>
<tr>
<td>Planting Methods Used in Oregon</td>
<td>6</td>
</tr>
<tr>
<td>Description of <em>Ammophila arenaria</em></td>
<td>10</td>
</tr>
<tr>
<td>DESCRIPTION OF THE STUDY AREA</td>
<td>15</td>
</tr>
<tr>
<td>METHODS USED AND ANALYSIS</td>
<td>23</td>
</tr>
<tr>
<td>RESULTS</td>
<td>29</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>40</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>45</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>47</td>
</tr>
<tr>
<td>APPENDIX I</td>
<td>51</td>
</tr>
<tr>
<td>APPENDIX II</td>
<td>63</td>
</tr>
</tbody>
</table>
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Areas planted between the Siuslaw River and the Siltcoos River showing species used, dates planted and acreages.</td>
</tr>
<tr>
<td>II</td>
<td>Frequency of occurrence of native species within each plantation.</td>
</tr>
<tr>
<td>III</td>
<td>Results of soil analysis for various ages of plantations.</td>
</tr>
</tbody>
</table>

### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Ammophila arenaria</strong> (L.) Link.</td>
</tr>
<tr>
<td>2</td>
<td>Map showing locations of the study areas.</td>
</tr>
<tr>
<td>3</td>
<td>Aerial view of the plantations south of the Siuslaw River.</td>
</tr>
<tr>
<td>4</td>
<td>Aerial view of the plantations north and south of the Siltcoos River.</td>
</tr>
<tr>
<td>5</td>
<td>Diagram of the sample plot.</td>
</tr>
<tr>
<td>6</td>
<td>Average density of <strong>Ammophila</strong> in each successive plantation.</td>
</tr>
<tr>
<td>7</td>
<td>Average cover of <strong>Ammophila</strong> in each successive plantation.</td>
</tr>
<tr>
<td>8</td>
<td>Average height of <strong>Ammophila</strong> in each successive plantation.</td>
</tr>
<tr>
<td>9</td>
<td>Average diameter of clumps of <strong>Ammophila</strong> in each successive plantation.</td>
</tr>
</tbody>
</table>
LIST OF FIGURES Continued

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>11</td>
<td>32</td>
</tr>
<tr>
<td>12</td>
<td>34</td>
</tr>
<tr>
<td>13</td>
<td>34</td>
</tr>
</tbody>
</table>

LIST OF APPENDIX FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>51</td>
</tr>
<tr>
<td>15</td>
<td>52</td>
</tr>
<tr>
<td>16</td>
<td>53</td>
</tr>
<tr>
<td>17</td>
<td>54</td>
</tr>
<tr>
<td>18</td>
<td>55</td>
</tr>
<tr>
<td>19</td>
<td>56</td>
</tr>
<tr>
<td>20</td>
<td>57</td>
</tr>
<tr>
<td>21</td>
<td>58</td>
</tr>
</tbody>
</table>
LIST OF APPENDIX FIGURES Continued

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Plantation with nine year old <em>Ammophila</em>, seven year old <em>Cytisus</em> and three year old <em>Pinus.</em></td>
<td>59</td>
</tr>
<tr>
<td>23</td>
<td>Plantation with ten year old <em>Ammophila</em>, nine year old <em>Cytisus</em> and six year old <em>Pinus.</em></td>
<td>60</td>
</tr>
<tr>
<td>24</td>
<td>Plantation with thirteen year old <em>Ammophila</em>, nine year old <em>Cytisus</em> and twelve year old <em>Pinus.</em></td>
<td>61</td>
</tr>
<tr>
<td>25</td>
<td>Plantation with 28 year old <em>Ammophila</em>, 27 year old <em>Cytisus</em>. <em>Picea sitchensis, Pinus contorta</em> and other natives are present.</td>
<td>62</td>
</tr>
</tbody>
</table>
DEVELOPMENTAL HISTORY OF EUROPEAN BEACHGRASS 
(AMMOPHILA ARENARIA (L.) LINK) PLANTINGS ON 
THE OREGON COASTAL SAND DUNES

INTRODUCTION

The problem of stabilizing mobile coastal sand dunes has been a worldwide concern for many years. Unstable sand in the form of dunes covers over three billion acres of the world's land surface, much of which is in coastal areas (44). Dunes occur along the Pacific coast at irregular intervals from the Strait of Juan de Fuca to Baja, California, on a total of over 90,000 acres. Of this 50,000 acres are found in Oregon alone (2; 23, p. 1).

Serious problems have arisen in Oregon from the encroachment of dunes on river channels, highways, homes, businesses and recreational facilities. Many of these dune areas have now been stabilized. An extensive planting program was undertaken between the Siltcoos and the Siuslaw Rivers for protection of the Siltcoos campground, the Siltcoos River channel, Honeyman State Park picnic area, and the Siuslaw River channel 1/. Planting has been carried on in this region since 1948. The U. S. Forest Service and the Bureau of Land Management in cooperation with the Soil Conservation Service have

---

1/ Information regarding areas planted, species used and reasons for planting was taken from U. S. Forest Service and Bureau of Land Management yearly reports on dune stabilization.
done most of the planting work.

Many experimental methods have been applied which include the planting of various beachgrasses and many woody shrubs and trees. Most successful and extensively used have been *Ammophila arenaria* (L.) Link (European beachgrass) plantings. *Cytisus scoparius* (L.) Link (Scotchbroom) and *Pinus contorta* Lour. (lodgepole or shore pine) were planted as the woody species to insure stabilization.

Development of these plantations is of interest to the individuals involved in the actual planting and stabilization work. They are primarily concerned with the planting's survival, growth and ability to stop movement of the sand. Permanent stabilization occurs with the growth of woody species. It is expected that the native species will eventually invade these plantations and replace the original planted species. The goal in stabilization is the development of the typical climax forest which occurred on the dune areas prior to the present sand movement.

Plantation development is also of interest ecologically. The *Ammophila* plantations offer excellent opportunity to observe the vegetational changes on these areas which were uniformly planted over a period of years. This study arose from a desire to note these vegetation changes in the successive plantations. The primary purpose was to observe the growth and development of *Ammophila* with age. Also of interest was the determination of changes in the growth
forms of *Cytisus* and *Pinus* and their effects upon the growth of the grass. Invading native species were observed to determine rates of their migration into the plantations. In addition, sand samples were analyzed to record changes which occur in the nutrient and organic make-up of the sand.
REVIEW OF LITERATURE

History of Planting Methods

Dune stabilization has been carried out for centuries. As early as 600 B.C. the dunes of d'Arcachon, France, were a menace to the capital cities of the Gauls. Threatened with sand inundation they undertook successful programs of seeding the dunes. In the 1700's dunes in western France were again active and it was at this time that major dune stabilization was begun. Two engineers, Bremontier and M. Grandjean, were hired by the French government to stabilize the dunes in the early 1800's. They developed new planting methods and by 1865 had completed stabilization. Later planting methods, used worldwide, were adapted from this early work (6; 7; 16; 19, p. 406-407; 21).

In France Ammophila was used exclusively for primary sand fixation. It was planted first to build a foredune and then to stabilize the main dune complex. Transplanting of the culms proved to be more effective than seeding the dunes. After primary fixation with the grass the secondary plantings were begun. Pinus seed was sown and nurse plants, especially Cytisus scoparius, were raised with the young pine (21).

The earliest reference to stabilization in northern Europe was in Germany in 1316 (44). The main dune cultivation developed in the
18th and 19th centuries. Methods which were used in Germany are described thoroughly by Gerhardt (8, p. 345-357). In 1583 a survey was conducted to observe dunes and their problems in Germany, but no stabilization work was done until 200 years later. In Denmark special planting techniques were developed in the 1700's. Gerhardt (8, p. 364-367) describes the methods developed by Sören, Biørn, Krause, Hagen and Roehl using primarily Ammophila.

Ammophila has been important in work done in Belgium, Holland, England, Scotland and Ireland (25, 28, 39). Some of the other countries which have used this grass include Australia, New Zealand, South Africa, Palestine, India and the Falkland Islands (7, 9, 15, 25, 26, 27, 29, 30, 35, 38, 39). Methods in these various countries differ according to the conditions in each and the degree of stabilization needed. In all of these countries woody species were planted to insure permanent stabilization.

The United States started a stabilization program in the early 1800's at Cape Cod. Congress appropriated funds between 1829 and 1854 to aid this program (25). The methods used at Cape Code were mainly transplants of the grass clones. Cytisus scoparius and various species of Pinus were used for permanent stabilization (19, p. 407). On the Pacific coast of the United States the first stabilization work was carried out at San Francisco, California, in 1896. This early planting used Ammophila with great success. Seed was
imported from Australia for use in production of the planting stock which was the first used on the Pacific coast (16; 19, p. 411; 22; 43, p. 61-63).

Planting Methods Used in Oregon

In the early 1900's work was begin along the Oregon coast. Until the 1930's planting involved primarily tree experimentation (16). A total of 75 species were tested for ability to survive on the Oregon dunes and the degree of stabilization they offered (4, p. 7).

The first major stabilization work with Ammophila was carried out by the Soil Conservation Service on the Clatsop Plains at Warrenton, Oregon, in 1935. This was done with the assistance of the Civilian Conservation Corps. The planting methods used became a model for later work along the coast (1; 23; p. 5; 24; 33; 36; 44).

The basic problem in stabilization of dunes is to still the sand near the source of origin or near the point of disturbance. Most effective is the establishment of vegetation which will survive inundation by sand or be able to keep pace with it (37). Many different grasses have been used for dune stabilization in different parts of the United States. On the Pacific coast four which are used with greatest success are Ammophila arenaria, Ammophila brevigulata Fernald, Elymus giganteus Vahl., and Elymus mollis Trin. (37, p. 515-517). A. arenaria is used most frequently as it is easy to
grow in nurseries, it readily withstands the severe climatic conditions and it is inexpensive to obtain.

A description of the methods recommended for planting on the Oregon coast are given by numerous authors (13; 23, p. 17-30; 37; 40). They are briefly summarized here. Transplanting of clones of *Ammophila* is definitely the most effective method of planting. The clones are obtained by undercutting two year old plants and separating the stems into convenient sizes for transplant (13). The stock is cleaned with culms totalling a length of 22 inches. The leaves are cut back to eliminate wind whipping. Planting stock is collected during the cool winter months when the plants are dormant and just before actual planting. Stock is obtained from nurseries set up primarily to provide planting stock. The nurseries must be maintained to produce two year old stock, which is best for transplanting.

The first stage in planting is construction of a foredune if one is not present. Behind the storm tide line an area approximately 400 feet in width and parallel to the coast is planted with *Ammophila*. A dune will be built from this. Planting is then begun on the lee of the foredune and continues with repeated plantings landward until it ties into existing vegetation. Density of the grass planting varies. On a windward slope clones are spaced at 18 x 18 inches with five culms per hill, on the hilltop spacing is 12 x 12 inches with three
culms per hill and on the lee slope spacing is 18 x 18 inches with three culms per hill. The clones are planted to a depth of 12 inches with the top eight inches remaining above the surface. In a study carried out by Brown and Hafenrichter (3, p. 519) it was determined that density was the most important factor in the production rate of Ammophila.

Fertilizers are necessary to insure survival and growth of the newly planted grass. Inorganic fertilizers are more effective than organic fertilizers. The nitrogen in the organic fertilizer is liberated more slowly than the inorganic nitrogen due to the cool coastal conditions. A nitrogen rate of 40 pounds per acre in one application in the form of ammonium compounds produces the greatest efficiency (3, p. 680-681; 23, p. 27; 37). The U.S. Forest Service and the Bureau of Land Management use 200 pounds of ammonium sulphate per acre on their plantations. Fertilizer is applied at the start of spring growth, generally during March and April after the winter rains have terminated. This prevents leaching of fertilizer through the soil too quickly.

Dates of planting are generally from November 1 through April 15. This depends on maximum temperatures. Survival of Ammophila will be less than 50 percent if it is planted in temperatures of 55° F. or above (23, p. 30; p. 518; 40).
Maintenance of the plantings is important. Many blowouts are replanted with *Ammophila brevigulata* (American beachgrass) because of its extensive root system and its greater ability to survive environmental extremes. It is less sensitive to climatic changes than *A. arenaria*, but because it is more expensive to obtain it is used less frequently in the planting programs. The greater expense is due to the difficulty of raising and maintaining this grass in the nurseries.

Secondary plantings are necessary for permanent stabilization. The most effective method of reforestation is to plant trees and shrubs in areas on which the grass has become established. Shrubs are planted for intermediate stabilization and trees are used for permanent stabilization. Many different species have been tried experimentally on the Oregon coast. The two recommended and most used are *Cytisus scoparius* and *Pinus contorta*. *Cytisus* is a leguminous plant introduced from northern Europe. It is recommended for use as it provides cover for the pine and adds nitrogen to the sand. The *Pinus* is native to the coast region. Both secondary species are obtained from nursery stock. *Cytisus* of 1-0 stock and *Pinus* of 2-0 stock are preferred. The 1-0 stock refers to a one year old plant which has not been transplanted and the 2-0 stock refers to a two year old plant with no transplanting. They are planted with a density of 6 x 6 feet to 8 x 8 feet. *Cytisus* is planted as
soon as the **Ammophila** forms a good cover. The **Pinus** is planted concurrently or in a later year (4, p. 17; 23, p. 39; 40). The availability of planting funds and of the planting stock determines the amount of secondary plantings made each year.

Similar basic planting procedures are utilized throughout the world. **Ammophila** provides the primary stabilizing vegetation and secondary woody species are used for permanent stabilization.

**Description of Ammophila arenaria**

**Ammophila arenaria** is in the tribe Agrostidae of the Gramineae family (Figure 1). It is closely related to **Calamagrostis** and has been placed erroneously in that genus. In the literature it is mentioned under the following scientific names: **Ammophila arundinacea** Host, **Arundo arenaria** L., **Calamagrostis arenaria** Roth, and **Psamma arenaria** Roen and Schuet. Common names are also numerous and include European Beachgrass, Marram, Gourbet, Sea Matweed and Holland Grass (16; 43, p. 61). **Ammophila** is derived from the Greek "ammos" meaning sand and "philos" meaning loving (12, p. 329).

This grass is native to the Atlantic coast of northern Europe but has been introduced worldwide on coastal dunes (12, p. 329; 14, p. 197; 43, p. 61). It is a coarse, erect perennial grass. The leaf blades are long, sharp-pointed and grow to a height of five feet.
Figure 1. *Ammophila arenaria* (L.) Link
The roots are deep with extensive scaly rhizomes. The panicles are dense, spikelike and often reach 12 inches in length (12, p. 329; 13; 14, p. 197; 17, p. 83). It flowers from the end of June through August. Little viable seed is produced. Reproduction is primarily vegetative, both by rhizomes and small basal buds. The rhizomes contain two roots and a bud at each node. The basal buds are located at the base of the stems under the lower leaf sheath and each can form a new plant (31; 42; 46, p. 14).

_Ammophila brevigulata_ is closely related to _Ammophila arenaria_. It is a native of North America and occurs as a sand-binding grass on the north Atlantic and Pacific coasts. The two grasses are similar and differ mainly in the length of the ligule (12, p. 329).

_Ammophila arenaria_ forms a natural hybrid with _Calamagrostis epigejos_ (L.) Roth. Both have a chromosome number of 2n=28 as reported by Löve and Löve (20, p. 68). The hybrid, _Ammophila baltica_ Link (2n=56), is sterile (14, p. 197).

The sand dune environment provides extreme climatic conditions to which few plants are well-adapted and are able to survive. _Ammophila_ produces its most vigorous growth under dune conditions. Therefore it is valuable in stabilization of sand dunes in coastal areas with severe wind erosion and low productivity. Its vigor depends upon the amount of blown sand which is deposited on the grass and it degenerates rapidly when sand deposition ceases (11, 18, p. 63-65;
The growth form makes possible survival under drifting sand. It is clumped in form and from each basal node produces five to six rhizomes and small leaves. On older parts of the rhizome leaves are lacking. Axillary buds are present and alive although only a small percentage of these viable buds develop. The leafy shoots continue to live after the rhizome from which they were derived has died, growing through the accumulated sand to produce new clumps. *Ammophila* also has the ability to produce adventitious roots from the buried portions of its erect stems, a feature making it well adapted to sand burial (10, 31). If the leaves are not more than one-half buried at a time, growth continues. The sand burial promotes elongation of the leaves and the development of adventitious roots. One-half to two-thirds of the summer's growth is often buried by the winter sand (19, p. 415-417). Ranwell (32) found it to tolerate three feet of sand deposition in one season. It is used not only for stabilization of mobile dunes but also in the actual construction of the foredune. The grass decreases the wind velocity causing a deposition of sand around its base. As the grass grows, more deposition occurs and the build-up of a dune is effected. Willis (46, p. 270-273) found wind shadows produced on the lee side of the grass and deposition of sand occurred up to 30 feet behind the vegetation. Accumulation of sand around the roots is due to eddies produced on the lee side which oppose the wind direction. There appears to be
an equilibrium established between the growth of the vegetation and the accumulation of sand which has definite effects on the survival of the grass. If the vegetation begins to be buried, resistance to wind decreases and therefore sand deposition decreases.

The success of Ammophila is related to the rigid nature of the leaves which give protection against scouring, the rapid growth in each season, the rapid multiplication of stems from underground buds and the development of extensive roots and in some cases underground stems (13; 23, p. 20).
DESCRIPTION OF THE STUDY AREA

Most of the sand dune complexes along the Pacific coast are associated with the rivers which empty into the ocean. The separate dune areas vary in length and width, extending landward in places up to a distance of 2.5 miles. Along the Oregon coast the Coos Bay dune sheet is most extensive. It ranges from Heceta Head south to Cape Arago, an approximate distance of 51 miles. This dune sheet is broken only by the Siuslaw and the Umpqua Rivers (5, p. 105; 23, p. 1). The area of the author's study is located south of Florence, Oregon, between the Siuslaw and the Siltcoos Rivers.

Cooper (5, p. 105) describes this area as follows. "It extends from the Siltcoos River north to the Siuslaw River, a distance of 19.0 km. The northernmost part is a peninsula, 6 km. long, outside the lower course of the Siuslaw River. The main body ranges from 2.4 to 3.5 km. in breadth. Within the area there have been stabilized dunes which only recently have been overwhelmed by active sand. For the entire distance only a narrow strip of stable dunes survive between Cleawox Lake and the Siltcoos River."

Prior to dune movement the forest occurred as far west as remnant stands which are still present in the open sand. Ninety percent of the area is now active sand. Dune movement between Florence and Coos Bay was caused by destruction of the stabilized
vegetation due to fire; the most recent occurring about 70 years ago (23, p. 1).

Three main dune-types occur along the coast and also on the study area (5, p. 27). The foredune or littoral strip is formed parallel to and nearest the ocean. Located farthest inland are oblique ridges, oriented in an east-west direction. These are exposed to both northwest and southwest winds and are positioned obliquely to both. The ridges are stable but need moving sand and ample space in which to occur. Between the littoral strip and the oblique ridges occurs the transverse-ridge. It is an unstable and actively moving dune formed at right angles to the wind directions, northwest and southwest. Transverse-ridge dunes are caused primarily by the northwest winds of summer and reach their maximum growth during these months.

Precipitation records from Reedsport, Oregon, 20 miles south of the study area, compiled over a period of 13 years, show a mean annual precipitation of 74.5 inches. Temperatures ranged from an average low January temperature of 43.7° to an average high in August of 60.9° F. The mean annual temperature was 44.1° and the mean annual maximum was 60.8° F. (41).

Wind is the most important factor in direction and amount of

---

2/ Taken from "The Oregon Dunes" by George H. Johnson, Chairman, Siuslaw Soil Conservation District, Florence, Oregon.
dune movement. Summer winds are primarily northwest, winter winds primarily southwest, and fall and spring winds are transitional. Wind data for Newport, Oregon, 50 miles north of the study area, showed the average wind velocity of July to range from 2.5 to 12.6 m.p.h. and velocity for January to range from 5.7 to 16.1 m.p.h. (5, p. 12).

On the Coos Bay dune sheet between Heceta Head and Coos Bay, planting was begun in the 1930's by the U.S. Forest Service. In 1935 areas at Sutton Lake, Siltcoos Recreation Area and Saunders Lake were planted to Ammophila. Other areas at Siltcoos were planted in 1937. All early work was carried out by the U.S. Forest Service. Following this planting was discontinued until it was initiated again in 1948. The U.S. Forest Service, Bureau of Land Management and the Soil Conservation Service undertook a cooperative program at this time to permanently stabilize certain parts of the dune area.

The recent work has been primarily south of the Siuslaw River and north and south of the Siltcoos River. A small area west of Cleawox Lake and its outlet has also been planted since 1962.

In the fall of 1949 planting was begun at the Siuslaw River by the Bureau of Land Management and the Soil Conservation Service. At the Siltcoos River area the U.S. Forest Service started its planting program in 1957.
Figure 2 is a map showing the region between the Siuslaw River and the Siltcoos River. The study areas are outlined on this map. Figure 3 shows an aerial view of the Bureau of Land Management and the Soil Conservation Service plantings south of the Siuslaw River. Figure 4 is an aerial view of the U. S. Forest Service plantings at the Siltcoos Recreation Area. The areas planted, species used, years planted and acreages are shown in Table I. The plantations are outlined on the photographs and are numbered according to Table I.

The planting programs in this area have been quite successful. At this time over 300 acres have been stabilized by the Bureau of Land Management and over 400 acres by the U. S. Forest Service.

---


4/ Aerial photographs obtained from U. S. Forest Service, Portland, Oregon. August, 1961. Scale approximately 1:15000
Figure 2. Map showing locations of the study areas.

A. Area shown in Figure 3.
B. Area shown in Figure 4.
Figure 3. Aerial view of plantations south of the Simlaw River.
Figure 4. Aerial view of plantations north and south of the Silcoos River. X indicates permanent plot.
Table I. Areas planted between the Siuslaw River and the Siltcoos River showing species used, dates planted and acreages.

<table>
<thead>
<tr>
<th>Map Plantation Number</th>
<th>Macro Plot No.</th>
<th>Ammophila Year</th>
<th>Acre</th>
<th>Cytisus Year</th>
<th>Acre</th>
<th>Pinus Year</th>
<th>Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siuslaw (Figure 3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>P-16</td>
<td>1964</td>
<td>29</td>
<td>---*</td>
<td>--</td>
<td>---</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1963</td>
<td>10</td>
<td>---</td>
<td>--</td>
<td>---</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1962</td>
<td>12</td>
<td>1963</td>
<td>--</td>
<td>1964</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1961</td>
<td>22</td>
<td>1963</td>
<td>--</td>
<td>---</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>1960</td>
<td>20</td>
<td>1962</td>
<td>--</td>
<td>1962</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>1958</td>
<td>10</td>
<td>1962</td>
<td>--</td>
<td>1962</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>1958</td>
<td>20</td>
<td>1959</td>
<td>--</td>
<td>1960</td>
<td>--</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>1957</td>
<td>32</td>
<td>1958</td>
<td>24</td>
<td>1962</td>
<td>--</td>
</tr>
<tr>
<td>9</td>
<td>P-7</td>
<td>1956</td>
<td>24</td>
<td>1958</td>
<td>24</td>
<td>1962</td>
<td>--</td>
</tr>
<tr>
<td>10</td>
<td>P-6</td>
<td>1955</td>
<td>23</td>
<td>1956</td>
<td>--</td>
<td>1959</td>
<td>--</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>1955</td>
<td>23</td>
<td>1959</td>
<td>--</td>
<td>1960</td>
<td>--</td>
</tr>
<tr>
<td>12</td>
<td>P-5</td>
<td>1954</td>
<td>25</td>
<td>1956</td>
<td>--</td>
<td>1960</td>
<td>32</td>
</tr>
<tr>
<td>13</td>
<td>P-4</td>
<td>1953</td>
<td>10</td>
<td>1956</td>
<td>--</td>
<td>1958</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>1953</td>
<td>53</td>
<td>---</td>
<td>--</td>
<td>---</td>
<td>--</td>
</tr>
<tr>
<td>15</td>
<td>P-3</td>
<td>1952</td>
<td>83</td>
<td>1956</td>
<td>66</td>
<td>1953</td>
<td>--</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>1950</td>
<td>36</td>
<td>---</td>
<td>--</td>
<td>1952</td>
<td>5</td>
</tr>
<tr>
<td>17</td>
<td>1951**</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td>---</td>
<td>--</td>
</tr>
<tr>
<td>Siltcoos (Figure 4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>P-15</td>
<td>1963</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>P-14</td>
<td>1962</td>
<td>63</td>
<td>1963</td>
<td>63</td>
<td>1963</td>
<td>63</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1962</td>
<td>60</td>
<td>1963</td>
<td>60</td>
<td>1963</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1962</td>
<td>10</td>
<td>1963</td>
<td>10</td>
<td>1963</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>P-13</td>
<td>1961</td>
<td>20.3</td>
<td>1962</td>
<td>--</td>
<td>1962</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>P-12</td>
<td>1960</td>
<td>72</td>
<td>1961</td>
<td>71.1</td>
<td>1961</td>
<td>71.1</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>1960</td>
<td>20</td>
<td>---</td>
<td>--</td>
<td>---</td>
<td>--</td>
</tr>
<tr>
<td>8</td>
<td>P-17</td>
<td>1959</td>
<td>8</td>
<td>1960</td>
<td>--</td>
<td>1960</td>
<td>--</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>1959</td>
<td>16.8</td>
<td>1960</td>
<td>17</td>
<td>1960</td>
<td>17</td>
</tr>
<tr>
<td>10</td>
<td>P-10</td>
<td>1958</td>
<td>64</td>
<td>1959</td>
<td>25</td>
<td>1959</td>
<td>--</td>
</tr>
<tr>
<td>11</td>
<td>P-9</td>
<td>1957</td>
<td>62</td>
<td>1958</td>
<td>54</td>
<td>1959</td>
<td>55</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>1957</td>
<td>11.5</td>
<td>1958</td>
<td>6</td>
<td>1959</td>
<td>--</td>
</tr>
<tr>
<td>13</td>
<td>P-1</td>
<td>1937</td>
<td>31</td>
<td>1938</td>
<td>--</td>
<td>---</td>
<td>--</td>
</tr>
</tbody>
</table>

* No record of acreage planted available.
** Replanted each year from 1951 to 1956.
*** Not shown on map (Figure 3).
METHODS USED AND ANALYSIS

Prior to the quantitative field work a survey of the area was undertaken to determine those areas best suited for study. Annual consecutive plantations over a 13 year period are located within the two study areas. Plantations of the 16 different years occurring in the area include 1937 and 1950 through 1964.

Overall, the number of years of plantings is limited. On some of the plantations the sequence of Cytisus and Pinus planting was not followed through and for some areas records were unavailable.

The 1937 and the 1950 areas were not sampled due to the incomplete planting sequence with Pinus and Cytisus. To keep sampling uniform only areas in which all three species had been planted were used. Altogether about 20 plantations were found on which the planting sequence had been completed. Therefore, selection of sample locations for each of the 13 years was possible. In 1951 90 percent of the grass plantation failed and it was replanted in 1952. Therefore, the 1952 plantation is the oldest area that was studied.

Another difficulty encountered was the lack of planting records for the Siuslaw area. The years in which planting of the secondary species occurred were more consistent and regular in the Siltcoos area than in the Siuslaw area. For this reason as many plots as possible were studied in the Siltcoos area with only older plantations observed in the Siuslaw region.
The plantations were varied in size and uniformity. Because of the variation within each strand, the varied topography, the size of the plantations and the planting success, location of a number of uniform samples within each stand was difficult. On some plantations a maximum of only one sample area was possible. In order to sample uniformly among the stands, one plot per stand was used.

The sample was taken from the most representative and uniform vegetation of the plantation. A level area away from the edges was chosen. No attempt was made to sample variation within each plantation as the primary purpose was to characterize the development of a specific planting by age. Areas with blowouts and unhealthy or dwarfed secondary species were also omitted from the samples.

In some of the plantations uniform areas were small. A macroplot of 25 feet by 25 feet was used as maximum sample size for equal sampling in all the plantations. The macroplot was divided in five foot square quadrats. Within each five foot quadrat a three foot square quadrat was placed. The macroplot and "nested" quadrat arrangement is diagrammed in Figure 5. The corner most closely oriented to the northwest was chosen as the base corner with the "west" side as the baseline. The baseline was placed at a 45° angle to the planted rows to avoid having quadrats parallel to the rows of the species.
Base Corner

\[ \times \] Location of soil samples.

Figure 5. Diagram of sample plot (macroplot).
Data for *Ammophila*, native herbaceous species, moss and litter was obtained from the three foot quadrat. Data for *Cytisus* and *Pinus* was obtained from the five foot quadrat. Information recorded for *Ammophila* included number of clumps present, average cover, diameter of clumps and height. Clumps of the grass were determined by the presence of green shoots. Each clump was surrounded with a varying amount of dead leaves. Data was taken only from the green shoots. Density was determined as the number of clumps per quadrat. Clumps less than half within a quadrat were excluded from the sample. Average cover was estimated on a percentage basis at six inches above the ground level. Diameter of the clumps and height of the grass were measured and averaged for each quadrat.

Native species were recorded as present or absent in each quadrat sampled. Frequency, the percentage of quadrats in which each species occurred, was calculated for each macroplot. Moss was listed if present and cover values estimated when greater than one-half percent. Litter was given an estimated cover percentage. Included in litter were dead *Ammophila* leaves both standing and broken, *Pinus* needles and *Cytisus* leaves and pods.

Data recorded for the shrubs and trees, *Cytisus* and *Pinus*, included number of individuals, percent cover, spread of the crown, and height. Density was calculated as the number of individuals per 25 foot plot. Average cover was estimated within each five foot
quadrat and totalled for the macroplot. Crown spread and height were measured with a yardstock for each individual. Individuals were included if one-half or more within a quadrat. All Cytisus plants were recorded if 12 inches or more high. Presence or absence of Cytisus seedlings were recorded for each five square foot quadrat. The frequency of the seedlings was calculated.

Soil samples were taken from each macroplot and also from old forest soil (about 100 years old), a 28 year plantation, a 15 year plantation and bare sand. On the macroplots samples were taken at the surface omitting any litter present. A 200 cc. sample was taken from the center of nine of the five foot quadrats. These were mixed in the field with a 200 cc. sample taken from this composite mixture as representative of the macroplot. Samples from the old soil, 28 year area, 15 year area and the bare sand were likewise taken at the surface. Three 200 cc. samples were taken at random within each location and a representative 200 cc. sample was taken from the composite.

Samples from only seven macroplots were analyzed. Changes in soil nutrients occur slowly enough that these samples give adequate representation. Analysis for pH, organic matter and total nitrogen was accomplished by the Oregon State University Soil Testing Laboratory. The methods used for the determinations were the soil-water paste for pH, Kjeldahl for total nitrogen and Walkley-Black
method for organic matter.

One macroplot (P-14) was permanently marked for future reference. It is located in the NW 1/4, Sec. 4, T. 20 S., R. 12 W. This is directly south of Wax Myrtle campground at Siltcoos Recreation Area. A three foot yellow wooden stake was placed at the northwest corner of the plot and marked with Botany Department, Oregon State University, 1964. The location of this plot is indicated on Figure 4.
RESULTS

Various features of Ammophila were shown by the data recorded with regard to the age of the plantations. Average density and average cover of the grass on each macroplot were calculated. These results are shown in Figures 6 and 7. The grass showed an increase from the density of newly planted grass of less than four clumps per quadrat to a peak at three years in which the most dense growth occurred (Figure 6). A general decline followed the three year old peak to a low at 13 years. Average cover of the grass showed a similar trend (Figure 7). Greatest cover was present in the three year old planting with a subsequent decrease to the 13 year plantation. In general, the height of Ammophila increased with age of the plantings although there was fluctuation between the various plots (Figure 8). At 13 years the greatest height was attained. In this plot Pinus and Cytisus offered considerable shade and cover. Average diameter of grass clumps was greatest at three years and also showed a decrease in size to the 12 and 13 year old plantings (Figure 9). By 13 years the clumped growth form had been partially replaced by single shoots of grass.

Density, height and percent cover were recorded for Pinus (Figure 10). Two year old pine was the youngest found on the plots. Cover and height increased generally from this age to the seven year old trees. No data was available for the eight, nine, ten and eleven year old stock. Height and cover were
Figure 6. Average density (number of clumps per three feet quadrat) of *Ammophila* in each successive plantation.

Figure 7. Average cover of *Ammophila* in each successive plantation.
Figure 8. Average height of **Ammophila** in each successive plantation.

Figure 9. Average diameter of clumps of **Ammophila** in each successive plantation.
Figure 10. Average height, average cover and density of Pinus at the various ages after planting.

Figure 11. Average height, average cover and density of Cytisus at the various ages after planting.
greatly increased by twelve years after planting. Density figures vary according to survival of the planting and have meaning only in showing a relationship to height and cover. Fluctuation in the height and cover values for the various ages of pine can be explained by the varying density. It follows that a reduced density would produce less cover. In the two year old trees density was higher but cover and height were lower due to the small size of newly planted stock.

_Cytisus_ also showed a relationship between density and cover although with height the relationship was less striking (Figure 11). Data was available for two to nine year old individuals. An increase occurred from the youngest to oldest both in cover and height. As in pine the youngest stock was high in density and low in height and cover. Differences in size of _Cytisus_ and _Pinus_ on the various macroplots can be seen in the photographs of the plots (Figures 16-24).

Frequency of _Cytisus_ seedlings was calculated and plotted according to the age of shrubs with which it occurred. There was an increase in frequency as the cover of _Cytisus_ increased (Figure 12).

The native species which were found in the various plots are listed with their frequencies of occurrence in Table II. The earliest occurring species, first observed in the three year plantation, were _Anaphalis margaritacea_ (L.) B. & H., _Hypocharis radicata_ L., and _Lupinus littoralis_ Sims with a frequency no greater than 24 percent. Of the herbaceous species _Senecio sylvaticus_ L. occurred in the
Figure 12. Frequency of Cytisus seedlings related to the age of mature shrubs.

Figure 13. Average cover of Cytisus, Mnium and litter in the various ages of Ammophila plantings.
Table II. Frequency of occurrence of native species within each plantation.

<table>
<thead>
<tr>
<th>Species</th>
<th>Age of Plantation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Anaphalis margaritacea</td>
<td></td>
</tr>
<tr>
<td>Hypochaeris radicata</td>
<td>12</td>
</tr>
<tr>
<td>Lupinus littoralis</td>
<td>24</td>
</tr>
<tr>
<td>Mnium sp.</td>
<td></td>
</tr>
<tr>
<td>Cladonia spp.</td>
<td></td>
</tr>
<tr>
<td>Fragaria chilensis</td>
<td></td>
</tr>
<tr>
<td>Aira praecox</td>
<td></td>
</tr>
<tr>
<td>Polytrichum juniperinum</td>
<td></td>
</tr>
<tr>
<td>Senecie sylvaticus</td>
<td></td>
</tr>
<tr>
<td>Eurhynchium oreganum</td>
<td></td>
</tr>
<tr>
<td>Brachythecium sp.</td>
<td></td>
</tr>
</tbody>
</table>

* Present

Table III. Results of soil analysis for various ages of plantations.

<table>
<thead>
<tr>
<th>Age of Plot</th>
<th>pH</th>
<th>Total Nitrogen (percent)</th>
<th>Organic Matter (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare sand</td>
<td>6.3</td>
<td>.001</td>
<td>.07</td>
</tr>
<tr>
<td>One year</td>
<td>6.0</td>
<td>.001</td>
<td>.00</td>
</tr>
<tr>
<td>Three years</td>
<td>5.5</td>
<td>.003</td>
<td>.00</td>
</tr>
<tr>
<td>Five years</td>
<td>5.7</td>
<td>.003</td>
<td>.00</td>
</tr>
<tr>
<td>Seven years</td>
<td>5.6</td>
<td>.007</td>
<td>.13</td>
</tr>
<tr>
<td>Nine years</td>
<td>5.4</td>
<td>.004</td>
<td>.07</td>
</tr>
<tr>
<td>Eleven years</td>
<td>5.6</td>
<td>.015</td>
<td>.20</td>
</tr>
<tr>
<td>Thirteen years</td>
<td>5.6</td>
<td>.012</td>
<td>.20</td>
</tr>
<tr>
<td>Fifteen years</td>
<td>5.0</td>
<td>.104</td>
<td>.80</td>
</tr>
<tr>
<td>Twenty-eight years</td>
<td>5.5</td>
<td>.080</td>
<td>.80</td>
</tr>
<tr>
<td>Old forest soil (approximately 100 years)</td>
<td>5.1</td>
<td>.054</td>
<td>1.34</td>
</tr>
</tbody>
</table>
11 year old planting with the highest frequency (48 percent) found on the macroplots. Among other natives Mnium sp. was found in 100 percent of the quadrats in the 11 and 12 year old plantings and in lesser frequencies in the other plots.

On a low, wet area which had been planted, many native species had invaded by the seventh year. On more favorable sites such as this an abundance of species can be found. Species observed on this area include: Festuca rubra L., Frageria chilensis (L.) Duch., Gnaphalium purpureum L., Hypochaeris radicata, Leontodon leysseri (Wallr.) Beck., Lupinus littoralis and Tanacetum camphoratum Less.

Litter and Mnium sp. cover were estimated (Figure 13). Mnium sp. was the most frequently occurring moss and the cover is given for this plant. Brachythecium sp., Eurhynchium oreganum (Sull.) J. & S. and Polystricum juniperinum Hedw. were also sparsely present but not in amounts great enough to warrant cover estimates. Litter and Mnium sp. were plotted according to the age of plantings. Both showed an increase with age. Litter was negligible in the one and two year plantings and increased generally in the remaining years. Mnium was first present in the five year sample and increased. Mnium cover generally follows Cytisus cover. It was observed to occur only beneath these shrubs, where shade and moisture would be more available.
Soil analysis of a few selected plots yielded the results shown in Table III. The pH decreased from 6.3 on bare sand to 5.1 on old forest soil with considerable variation among plots of intermediate age. Organic matter and total nitrogen showed a general increase in amount with age. Organic matter on the bare sand was higher than on the one, three and five year plots and increased in the older areas.

Photographs of some of the plantations sampled are included in the Appendix. These include Ammophila plantations of one, two, three, four, five, six, eight, nine, ten, thirteen, and twenty-eight years of age. Because of the similarities between the seven and eight year, and the eleven, twelve and thirteen year plantations, photographs of only the eight and thirteen year areas are included to represent those plantings. General overall appearance of the plots changed from the regular spaced clumps of grass in the one and two year plantings to the dense growth of Cytisus and Pinus combined with sparse grass in the thirteen year planting (Figures 14, 15 and 24).

On the thirteen year old planting Pinus was taller than the Cytisus. This was the only area in which the Pinus had been planted before the Cytisus. The increased cover of the woody species was probably the influencing factor in the increased height growth of Ammophila found on this plot.
Much experimental planting work had been done with various species. On the nine year plantation one individual of Lupinus arboreus Sims was noted. This was probably planted at the time of the Cytisus planting as an experimental species.

A 28 year planting was observed but no plots were sampled (Figure 25). Vegetation was dense with Pinus contorta, Picea sitchensis (Bong. ) Carr. and Cytisus scoparius the most prominent species. Ammophila and Cytisus were the only species not native to the area. Pinus and Picea were ten to 25 feet tall. Cytisus was tall and thin with leaves only at the top. Many dead individuals were present with some regeneration in the more open areas. Understory vegetation was comprised of the following herbaceous species: Achillea millefolium L., Aira praecox L., Anaphalis margaritacea, Cladonia spp., Festuca rubra, Frageria chilensis, Gaultheria shal-lon Pursh, Hypochaeris radicata, Poa confinis Vas., Polygonum paronynchia C. &S., Polytrichum juniperinum, Vaccinium ovatum Pursh and unidentified ferns. Ammophila was present but in unhealthy condition and with no clumped growth form.

Many factors affect data such as the proximity of the plantation to native vegetation, degree of plot protection from wind and sand, health of the planting stock, and climatic and environmental conditions which determine the success of the planting. With such variation between plantings, conditions and results for the various
ages differ.

Further work could include more extensive sampling within each of the plantations and sampling of areas planted in other years. This would give a more complete picture of the vegetation changes on these plantations and of the changes within the Ammophila.
DISCUSSION

Growth form of *Ammophila* showed a definite change in appearance with age. Density, height and diameter of clumps increased to the maximum at three years. The higher density would naturally lead to a higher percent cover. With age the leaves on the outer edge of the clump die leaving small bunches of shoots within. Thus the diameter of the clumps decreases with age. The reduced amount of sand drift after three years accounts for this decrease in growth. Sand was readily available near the three year plot but was less available after this age. If the four year area were nearer open sand and had less protection, a decrease in growth might not have occurred.

*Ammophila* has been observed to have the following habit types (10). On a foredune with actively moving sand, clumps with a few young plants were present. On a stable dune the grass formed tussocks, between which occurred other species and a few dead and live shoots. In an area sheltered from the wind uniformly distributed and isolated shoots occurred. This was similar to the growth observed on the author's sample area.

The overall increase in height of *Ammophila* can be related to the increase in combined cover of *Pinus* and *Cytisus*. The tallest grass found in the 13 year plot may be due to the increased amount
of shade and cover of Pinus and Cytisus found in this plot. Fluctuations in height among the plantations occur due to the variation of the sites in proximity to open sand and protective vegetation and exposure.

Pinus showed an increase in height with age. The increase was more rapid from the eight to 12 years than from two to seven. Data was unavailable for the eight to 11 years so actual rates of growth in these years are not known. With age it is expected to find increase in growth. The tallest form of the Pinus was in the 12 year old individuals. Density and cover were also greatest in this year. With greater density cover is increased. In this plot the Ammophila was 13 years old and the Cytisus nine years old (Figure 24). The Pinus had been planted before the Cytisus and had an opportunity of growth before competition. This accounts for the greater height of pine in this plantation.

In Cytisus little growth occurred during the first year after the transplant. By the third year the plants had increased in height and greatly increased in cover mainly due to the spreading lateral branches. Height increased little after five years of growth. This is probably the maximum growth possible on these plots as they are the tallest species and are subject to full force of the wind which serves to stunt growth. In the 28 year old plantation Cytisus reached 14 feet or more in height. Here it was sheltered by the taller trees
and with this protection was able to attain a greater height.

_Cytisus_ seedlings appeared for the first time in the plot where _Cytisus_ shrubs were five years old. Four or five years are probably required before _Cytisus_ seed production and consequent production of seedlings. The frequency of occurrence of seedlings showed a direct relationship to the amount of cover offered by the shrubs. Occurrence is due to the amount of shade and cover present.

The time of year in which the sampling was done as well as the location of the plot in relation to areas where native species occur naturally are important. More native species could invade an area which was closer to natural timber than a more distantly located area. The plantation near the low, wet area was much more favorable for invasion of species than dry dune areas, thus many more were present and in greater numbers.

Litter cover increased with the production of dead material and debris from the _Cytisus_ and _Pinus_. _Mnium_ increased with cover of _Cytisus_. Moss was observed only under the branches and shade of the shrubs.

Nutrients present in the dune soil have an important influence on the growth of the vegetation. On an English dune nitrogen and phosphorus were found to be limiting factors in determining the vegetation of an area. Any soluble nutrients present rapidly leach from the sand (46, p. 270). The three factors of major importance
in the sand dune are pH, organic matter and nitrogen content. On an area developing from a foredune with only Ammophila present to a stabilized dune with permanent vegetation, the following conditions occur. The pH decreases, nitrogen increases and organic matter increases. The decrease in pH is related to the increase in nitrogen and organic matter (34; 46, p. 16; 47).

The sand samples taken from the study plots were analyzed for the three factors: pH, total nitrogen and organic matter. The analysis showed a definite decrease in pH from bare sand to old soil. Results showed a variability during the intervening years. Organic matter was definitely greater in the old soil than in the others but few changes appeared within the plots. Higher organic matter in bare sand is difficult to explain unless through the accumulation of wind-blown organic matter from the foredune and beach or the plantations. Total nitrogen showed an increase although values were of such small percentages that they could not be considered important. The samples were taken at the surface which would introduce some error into the sample from any wind-blown sand present. Sampling at a depth of about two inches would have been more effective. Analysis would give different results if the samples were taken at another time during the year. These samples were taken in November after a season of growth and before the winter rains. A series of samples taken in the spring would give an
interesting comparison.

The vegetation of the 28 year old plantation is probably typical of that which will eventually occur on the more recent plantations. There were no plantings made during the years 1938 to 1950. It would be interesting to study the vegetation changes occurring during this time. In time a typical climax forest vegetation with no Ammophila, Cytisus or Pinus present will develop on the areas now being planted. It can be expected with reasonable certainty that the recent plantations will develop to the stage now found in the 28 year old area and then to the climax forest. Major trees in the climax forest are Picea sitchensis and Tsuga heterophylla (Raf.) Sarg. (Western hemlock). Western hemlock develops only where protection from winds bearing salt has been provided.
CONCLUSIONS

Thirteen consecutive years of Ammophila plantations were observed on the Oregon coastal sand dunes. Vegetation changes on plantations made from 1952 to 1964 were studied.

Ammophila reached its maximum growth in density, cover and diameter of clumps at three years of age. After this it generally decreased to the 13 year old plantation. Height increased to a maximum of 13 years with minor fluctuations occurring between the plantations. Dense clumps occurred with maximum growth but by 13 years few clumps were present and solitary shoots occurred.

Pinus and Cytisus also showed general increases in height and cover with age, with Cytisus reaching its maximum development at about six years of age. Seedlings of Cytisus were closely related to the shrub cover and they were most abundant after five years.

Native species occurred sparsely within the plantations. Mnium was one of those species which showed the most vigorous growth and increased rapidly in amount with age of the plantation. Soil analysis showed a decrease in pH with age of the plantation and a general increase in organic matter. Nitrogen was present and showed a slight increase with age.

In the observation of a 28 year old plantation many native species were noted as were individuals of Pinus contorta and Picea sitchensis,
both of which occurred naturally. In time the Ammophila and Cytisus present in this area will disappear and be replaced completely with native species. It is expected that the areas now being planted will develop this typical climax vegetation.

Sand dune control through the introduction of plant species adapted to various stages of the developing forest appears to be successfully initiated in this area.
BIBLIOGRAPHY


36. Steele, T. A. Grass and associated vegetation to reclaim Oregon's coastal sand dunes. Soil Conservation 6:43-44. 1940.


APPENDIX I

Photographs of Sample Areas

Figure 14. Plantation showing one year old *Ammophila*. 
Figure 15. Plantation showing two year old *Ammophila*. 
Figure 16. Plantation showing three year old *Ammophila* and one year old *Cytisus* and *Pinus*. Permanent plot facing south.
Figure 17. Close-up view of the three year old *Ammophila* plantation.
Figure 18. Plantation showing four year old Ammophila, three year old Cytisus and Pinus.
Figure 19. Plantation with five year old *Ammophila*, four year old *Cytisus* and *Pinus*. 
Figure 20. Plantation with six year old *Ammophila*, five year old *Cytisus* and *Pinus*. 
Figure 21. Plantation with eight year old *Ammophila*, seven year old *Cytisus* and six year old *Pinus*. 
Figure 22. Plantation with nine year old *Ammophila*, seven year old *Cytisus* and three year old *Pinus*. 
Figure 23. Plantation with ten year old *Ammophila*, nine year old *Cytisus* and six year old *Pinus*. 
Figure 24. Plantation with thirteen year old Ammophila, nine year old Cytisus and twelve year old Pinus.
Figure 25. Plantation with 28 year old *Ammophila*, 27 year old *Cytisus*. *Picea sitchensis*, *Pinus contorta* and other natives are present.
APPENDIX II

Introduced Species and Species Used in Plantings

Ammophila arenaria (L.) Link
Ammophila baltica Link
Ammophila brevigulata Fernald
Calamagrostis epigejos (L.) Link
Cytisus scoparius (L.) Link
Elymus giganteus Vahl.
Elymus mollis Trin.
Lupinus arboreus Sims
Pinus contorta Lour.

Native Species

Aira praecox L.
Achillea millefolium L.
Anaphalis margaritacea (L.) B. &H.
Brachythecium sp.
Cladonia sp.
Eurhynchium oreganum (Sull.) J. &S.
Festuca rubra L.
Fragaria chilensis (L.) Duch.
Gaultheria shallon Pursh
Native Species Continued

Gnaphalium purpureum L.
Hypochaeris radicata L.
Leontodon leysseri (Wallr.) Beck.
Lupinus littoralis Dougl.
Mnium sp.
Picea sitchensis (Bong.) Carr.
Poa confinis Vas.
Polygonum paronychia C. &S.
Polytrichum juniperinum Hedw.
Senecio sylvaticus L.
Tanacetum camphoratum Less.
Tsuga heterophylla (Raf.) Sarg.
Vaccinium ovatum Pursh