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Table 10. Influence of the age of the plants on nodulation.

<table>
<thead>
<tr>
<th>Age of the plants (days)</th>
<th>Amount of nodule material (mg)</th>
<th>Number of nodules on three plants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>2 19 37</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2 13 0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>0 3 3</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1 0 0</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>96</td>
<td>6 5 3</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1 0 0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>110</td>
<td>0 1 0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0 0 0</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>0 0 0</td>
</tr>
</tbody>
</table>

In plants older than 50 days nodulation decreased sharply, but in a second experiment 70-day-old plants showed very good nodulation (equalling that of the “50-day-plants” of experiment I), whereas 77-day-old plants were hardly nodulated (like the “110-day-plants” of experiment I).

The results show unequivocally that the age of the plant has an influence on nodule formation. It is not clear, however, what age is optimal for nodulation. The main reason for the divergent results of the two series of experiments is that the plants were cultivated in the greenhouse, where climatological conditions vary strongly during the year. Therefore, the age of the plants is not the best parameter for the condition of such plants at the moment of inoculation. These experiments will be repeated next year with plants cultivated in phytotrons to eliminate the variation in climatological conditions.

6.3. THE INFLUENCE OF TRAMPLING AND SOIL COMPACTNESS ON THE DISTRIBUTION OF SOME Plantago species (C. W. P. M. Blom)

6.3.1. Introduction
One of the subjects of the ecological research in the dune areas on Voorne and Goeree concerns the influence of recreation and grazing on
the vegetation. The dunes in these regions are under strong recreational pressure, and, in addition, grazing was started a number of years ago as a form of management. One effect of both recreation and grazing is trampling of the vegetation, which is accompanied by compaction of the soil.

The aim of this study is to determine the influence of the soil compactness on the development of the natural vegetation and on the distribution of some plant species. To obtain an impression of the influence of soil compactness, some indicative Plantago species were chosen for investigation, because soil compactness is thought to be of importance for the distribution of these species.

A synecological field study is expected to provide a basis for the formulation of a working hypothesis concerning the distribution of plant communities including Plantago species, and concomitant experimental work was started in 1971. Some aspects of the synecological study and the methods and preliminary results of the experimental studies are described here.

6.3.2. Synecological study

Some of the dune grassland vegetations of Voorne and Goeree are exposed to severe recreational pressure or grazing, mainly by cattle. Recreation takes place on the Heveringen, an old grassland formation in the dunes of Voorne, and grazing occurs, for instance, on the Westduinen on Goeree. The synecological situation is being studied mainly in those areas. This field work can be briefly described as follows.

The vegetation of sample plots is described annually by means of the Braun-Blanquet method. The plots were selected mainly along paths where Plantago species are present. The aim is to obtain an impression of the connection between the Plantago species and other plant species in relation to edaphic factors such as trampling and soil compactness.

Another aspect of this field work is the analysis of seasonal periodity and fluctuation of the species in the different localities in relation to different soil characteristics.

In the future the shoot/root ratio of the species under consideration will be determined. As an example, Table 11 shows the results of three vegetation analyses made in the Westduinen area, i.e. on a cattle path (plot I), just beside this path (plot II), and on a slight slope (plot III) close to these plots.

6.3.3. Experimental work

6.3.3.1. Material and Methods

To investigate the relationship between the distribution of plant species and various environmental conditions a distinction must be made between the germination and the development of the seedling. In this research
Table 11. Vegetation analysis performed in the Westduinen area of Goeree (1972)*.

I. Plot on a cattle path.
II. Plot just beside this path.
III. Plot on a slight slope close to the plots I en II.

<table>
<thead>
<tr>
<th>Plot nr.</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of the plot in cm</td>
<td>30 x 150</td>
<td>50 x 150</td>
<td>50 x 150</td>
</tr>
<tr>
<td>Cover herb layer in %</td>
<td>60</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Cover moss layer in %</td>
<td>5</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Height herb layer in cm</td>
<td>3</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>Trampling (+ present; ± sometimes; — absent)</td>
<td>+</td>
<td>±</td>
<td>—</td>
</tr>
</tbody>
</table>

- **Plantago lanceolata**
- **Plantago major**
- **Plantago coronopus**
- **Potentilla anserina**
- **Bellis perennis**
- **Trifolium micranthum**
- **Cerastium arvense**
- **Carex paniculata**
- **Carex flauca**
- **Agrostis tenuis**
- **Anthoxanthum odoratum**
- **Trifolium repens**
- **Ranunculus acris**
- **Spergularia rubra**
- **Linum catharticum**
- **Radiola linoides**
- **Potentilla erecta**
- **Festuca rubra**
- **Briza media**
- **Sieglingia decumbens**
- **Luzula campestris**
- **Rhytidiadelphus squarrosus**
- **Brachythecium albinum**

Species not included here:

- **Festuca ovina** +, **Poa pratensis** +.
- **Plantago intermedia** r, **Hierachium pilosella** +, **Hydrocotyle vulgaris** 2, **Hypochaeris radicata** +, **Lotus corniculatus** +, **Leontodon nudicaulis** +, **Cerastium holosteoides** +, **Crepis biennis** 1, **Viola rupestris** +, **Carex nigra** +, **Carex trinervis** 1, **Agrostis stolonifera** +.
- **Lotus corniculatus** 2, **Euphrasia officinalis** 2, **Polygala vulgaris** 1, **Rumex** +, **Hypochaeris radicata** 2, **Ornithopus perpusillus** +, **Ranunculus bulbosus** +, **Viola rupestris** +, **Crepis capillaris** r, **Taraxacum erythrospermum** +, **Cynosurus cristatus** +, **Carex nigra** +, **Agrostis stolonifera** +, **Carex arenaria** +, **Cladonia rangiformis** +.

* Symbols: r: 1-5 specimens.
  +: 5-100 specimens; basal covering 1-5 %.
  1: many specimens; basal covering 1-5%.
  2: basal covering 5-25%.
  3: basal covering 25-50%.
period the influence of soil compactness was studied mainly on the basis of the germination of seeds of *Plantago major*, *Plantago lanceolata*, and *Plantago coronopus*, all collected on Voorne and Goeree in 1971, as well as the germination of seeds of *Plantago media* collected in Zuid-Limburg in 1972.

The seeds were stored in envelopes at room temperature. Germination occurred in plastic boxes (37×29×10 cm) filled with sand originating from the older dunes (humus content about 0.5%; pH ± 9). The tests were carried out in the greenhouse of the Biological Station. The substrate was chosen because all of the mentioned *Plantago* species except *media* are normally present on the older dune sand. *Plantago media* was included to permit comparison of the *Plantago* species occurring in the dunes with a plant species originating from another area.

The following treatments were applied. Three series were prepared: in series A the soil was not compacted, in series C there was a maximal compaction, and in series B moderate compaction. Compaction of the soil was achieved by ramming down the substrate. Soil compactness was determined by measurement of the soil resistance with a penetrometer. The soil resistance in the upper 2 cm was 0 kg/cm² in series A, 5 kg/cm² in series B, and 10 kg/cm² in series C. The percentage of water in the substrate was kept constant during the experiments. In each box two plant species were sown (200 seeds of each species).

For the controls, the seeds were placed on wet filter paper in petri dishes which were held in the dark in the greenhouse. The substrate and the filter papers were kept moist with distilled water. In the greenhouse the day temperature was about 27° C and the night temperature about 22° C.

6.3.3.2. Results

The results of these germination experiments are shown in Fig. 3 (mean values of two experiments). In total, the germination of 400 seeds per plant species was studied. The germination percentage showed no variation during the whole of 1972, except for *Plantago major*. The graph of *P. major* shows the results of two experiments, one carried out in August and the other in October, both performed in triplicate.

6.3.3.3. Discussion

The maximal germination percentage and the germination rate of the *Plantago* seeds differ between the substrates with different compactness. In general, the seeds on the dune soils without compaction showed the highest germination percentage and maximal germination was reached sooner than in the other series.

The lowest germination was generally obtained in the dune soils with the highest penetrometer resistance. For *Plantago major*, the difference between the maximum germination in series A (no compaction) and
Fig. 3.

* Plantago major

- series A
- series B
- series C
- control

* Plantago media

- time (days)

Fig. 3.
Fig. 3. Influence of soil compactness on the germination of four *Plantago* species.

Series A: Soil resistance 0 kg/cm².
Series B: Soil resistance 5 kg/cm².
Series C: Soil resistance 10 kg/cm².
series B (soil resistance 5 kg/cm²) was significant, and similar differences were found for *Plantago media* between series A and C and B and C (χ²-test by Fischer; P < 0.05).

Germination of the seeds of *Plantago major* and *Plantago media* proved to be season dependent: in the winter under laboratory conditions these species showed no germination. The experiments will be continued at other times of the year and under additional conditions, for instance varying soil compactness during germination, and the direct influence of trampling will also be investigated.

J. W. Woldendorp

### 7. Publications in 1972


---------, Natuur en mens, 29e Congres Ideologie en Natuurbeleving Mechelen (B), 13-16 (1972).


--------- and E. Heeres, Welke soort zwenkgras (Festuca rubra s.l.) komt voor in de jonge kustduinen van Voorne en die van overig Nederland? Gorteria 6, 57-61 (1972).


**Speek, B. J.**, Ringverslag van het Vogeltrekstation nr. 55, Limosa 44,

---------, How to read the EURING-recovery punch card (Publication of the Institute, 1972).


