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THE DISTRIBUTION OF SENECIO JACOBAEA L. AND TYRIA JACOBAEAE L. IN RELATION TO SOIL PROPERTIES

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SUMMARY

The distribution of *S. jacobaea* in The Netherlands is compared with local water-table depth, degree of drainage and calcium content. As surface units, hour squares (5.25 km × 5.25 km) are used. Water-table depth accounts for a greater part of the variance in the distribution of Ragwort than soil drainage. The variance accounted for by water-table depth and calcium content is of the same order. In the category of soils which have a low water level and are calcareous at the same time, Ragwort is very frequent (in 96% of the squares).

A significant relation of the distribution of the main consumer of Ragwort, *T. jacobaeae*, to soil drainage, as was found in England and Wales, could not be shown for The Netherlands. However, indications are given that egg distribution of *T. jacobaeae* is related to the area and density of Ragwort populations.

1. INTRODUCTION

According to CAMERON (1935), "Ragwort (*S. jacobaea*) is essentially a plant of well-drained and even dry soils. It grows on the shallow, highly calcareous soils derived from chalk, on sand-dunes, on chalky sands, on derelict arable land, and neglected and overgrazed pastures". HARPER & WOOD (1957), when describing the substratum of the plant, write that it is "absent where the water table is high or the soil is maintained near field capacity... Abundant on light disturbed calcareous soils". Neither of them, however, gives a quantitative analysis of the distribution in relation to the soil properties mentioned.

In The Netherlands, Ragwort occurs in the greater part of the country. It is scarce in the north-eastern provinces and in the region with low-lying soils immediately bordering the western coastal dunes *(fig. 1)*. These records are compiled by the department "Nederland" of the Rijksherbarium at Leiden (MENNEMA, in prep.). Although there is no information available on the abundance and "microdistribution" of Ragwort in each of the squares, the data collected on presence or absence provide the possibility of comparing the distribution of the plant with the soil characteristics. By placing a photographic transparance of the grid of so called "hour squares" (used for the inventory of the flora; one hour square = 5.25 km × 5.25 km) on top of a map showing soil properties, the dominant situation in each compartment of the grid can be ascertained. Due to the size of the grids used, the classification cannot be very detailed.

For the present purpose, the distribution of Ragwort was compared with the water-table depth, the degree of drainage, and the calcium content of the soil. The "ATLAS VAN NEDERLAND" (1961) (map VII–6; 1:600,000) provides infor-

mation on water-table depth (winter values), maps IV–10 and 12 from the same atlas give information on the calcium content of the soil; the degree of drainage was read from the "General soil suitability map for arable land and grassland of The Netherlands" (1:200,000) + explanation (VINK & VAN ZUILEN 1967).

It is the aim of this paper to test whether relations can be found between these soil properties and Ragwort distribution on the scale mentioned. Evidently, these relations are not solely a reflection of the physiological properties of

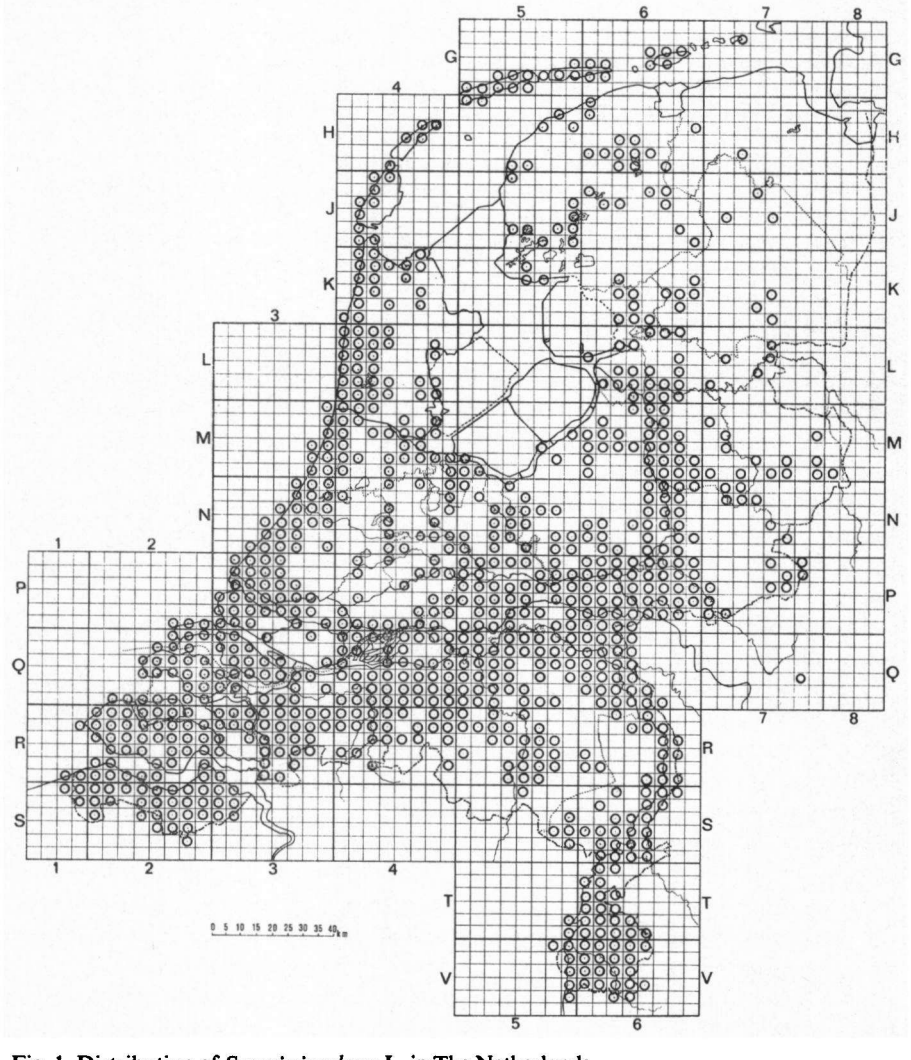

Fig. 1. Distribution of *Senecio jacobaea* L. in The Netherlands.

the plant species, but they are the result of the combined influences of all biotic and abiotic factors acting in the biocoenosis.

Additionally it is tested whether the distribution of the Cinnabar Moth (*Tyria jacobaeae* L.), an important pest of Ragwort, is related to the degree of drainage of the soil, as was mentioned by DEMPSTER (1971) for England and Wales.

Although the data used are the result of many years of observation, the records of the distribution of the plant as well as the insect are probably still incomplete. For a small number of squares information was not available on all soil properties. As a consequence figures may differ slightly in the following tables. The total number of squares used is 1874; Ragwort was recorded in 903 of them.

2. SOIL PROPERTIES AND RAGWORT DISTRIBUTION

2.1. Water-table depth

A division was made into three categories:

a. water level ranging from 0–20 cm below soil surface;
b. water level ranging from 20–100 cm below soil surface;
c. water level more than 100 cm below soil surface.

In *table 1* the numbers of squares in which Ragwort occurs in the different categories are given together with the percentages which they constitute of the total number of squares present in each category (column totals). From the total number of squares and the number in which Ragwort occurs, it was calculated for each category in how many squares Ragwort should have occurred if its presence were completely independent of the water-table depth. The differences between expected and actual numbers were tested (χ^2-test). As appears from *table 1*, Ragwort is present in significantly more squares with a low water level than expected.

2.2. Degree of drainage

Four categories of squares are distinguished. The following list only mentions the main soil types.

a. Poorly drained soils: (very) low peat soils, low (peaty) sand soils (gley and podzol soils);
b. Moderately drained soils: low peat (reclamation) soils, low sand soils (podzol, dune sand and sea sand soils), predominantly non-calcareous heavy sea clay and river clay soils, low and medium high Loess soils;
c. Well drained soils: medium high peat (reclamation) soils, medium high sand soils (podzol soils and old arable land soils), medium high river clay soils, soils of the Zuiderzeebottom, Loess soils;
d. Very well drained soils: high sand soils (podzol soils, drift sand dunes).

S. jacobaea is found in significantly more squares with very well and well drained soils than in those with wetter soils (*table 1*, row totals).

Table 1. Distribution of Ragwort in relation to water-table depth and soil drainage.

	drainage									
	poor		moderate		well		very well		total	
water-table depth	squares present	squares with Ragwort	sp	sR	sp	sR	sp	sR	sp	sR
0–20	161	61 (40%)	47	11 (23%)	29	7 (24%)	2	2 (100%)	239	81 (34%)
20–100	87	27 (31%)	433	159 (37%)	577	311 (54%)	184	74 (40%)	1281	571 (45%)
>100	2	1 (50%)	15	10 (67%)	84	72 (86%)	219	142 (65%)	320	225 (70%)
total	250	89 (36%)	459	180 (36%)	690	390 (57%)	405	218 (54%)	1840	877 (48%)

χ^2 water-table depth – Ragwort: 46.52; $p < 0.005$
χ^2 soil drainage – Ragwort: 35.48; $p < 0.005$

2.3. Relation between water-table depth and soil drainage

Water-table depth and natural drainage are closely related factors, as can be seen in *table 1*: the majority of squares with a high water level is poorly drained; most of the squares with an intermediate water level are well or moderately drained; most of the squares with a low water level are very well drained. To test which of the two factors accounts for the greater part of the variance in *table 1*, a technique was used, based essentially on a two-way layout analysis of variance (with one observation per cell). A classification was made into three water-table depth categories (i = 1, 2, 3) and four soil drainage categories (j = 1, 2, 3, 4). The probability of finding Ragwort in cell (i, j) can be thought to be composed of separate components.

$$p_{ij} = p \cdot p_i^{W} \cdot p_j^{D} \cdot p_{ij}^{WD} \qquad (1)$$

in which

- p = the probability (geometrical mean) of finding Ragwort in a randomly chosen square,
- p_i^{W} = the influence of water-table depth on this probability (if $p_i^{W} < 1$, then the probability of finding Ragwort in squares with water-table depth (i) is smaller than the probability of finding Ragwort in a randomly chosen square; if $p_i^{W} > 1$, this probability is greater. The p_i^{W}'s are chosen in such a way that the mean influence of water-table depth on all squares is 1, i.e. there is no influence).
- p_j^{D} = the influence of soil drainage on p (see p_i^{W}).
- p_{ij}^{WD} = the influence of the interaction between water-table depth and soil drainage on this probability.

Since the influences on p are assumed to be of a multiplicative character (1),

the frequencies *(table 1)* were transformed into logarithms to execute the analysis of variance. In calculating p, p_i^W and p_j^D, it was taken into account that some combinations are very commonly represented and others only rarely by weighing the frequencies of Ragwort occurrence with the number of squares present in each cell (for details of this weighing technique see SCHEFFÉ (1964)). The values of p_i^W and p_j^D are given below.

$p_1^W = 0.78$ $p_1^D = 0.96$
$p_2^W = 0.94$ $p_2^D = 0.83$
$p_3^W = 1.53$ $p_3^D = 1.21$
$p_4^D = 0.93$

(Figures for p_{ij}^{WD} are not given, since apart from being a measure for the interaction, they also contain the rest-variance. These two components cannot be separated.)

Since the extreme values of p_i^W differ much more than those of p_j^D, it may be concluded that the influence of water-table depth on the distribution of Ragwort is more important than the influence of soil drainage.

The relation found between water-table depth, soil drainage and Ragwort distribution does not exclude the possibility that Ragwort might grow equally well on less dry soils. Competition from the local vegetation may prevent the plant from extending its range into the latter habitats. Cameron's (1935) conclusion that the plant will not stand intense competition from grasses supports this assumption.

My own observations in the dune area between The Hague and Wassenaar agree with this idea. Here, unexpectedly, Ragwort was found not only in the extensive dry areas, but also in some moist localities where the vegetation had been disturbed or where no vegetation at all was present. Also, sowing experiments carried out in different vegetations in these dunes, showed that a much higher proportion of the seeds sown germinated and became established in plots where the vegetation had been removed than in undisturbed plots in their immediate vicinity.

The number of plants established in these plot pairs, one and a half year after sowing, is shown in *table 2*. It appears that on those soils which in itself are most favourable for Ragwort settlement the naturally present vegetation has a very pronounced negative effect on the number of plants. (Full data will be published elsewhere.)

Table 2. Effect of interspecific competition on Ragwort settlement (plot size: 30 cm × 30 cm; number of seeds sown per plot: 1500).

number of plants per vegetation-free plot	number of plotpairs	total number of plants on vegetation-free plots (a)	total number of plants on plots with vegetation (b)	b/a × 100
0–10	13	50	61	122
11–20	6	80	41	51
>20 (max. 45)	6	202	7	3

2.4. Calcium content

Soils are divided into predominantly calcareous (> 0.5% calcium in the upper soil layer) and predominantly non-calcareous. Ragwort is present in significantly more squares of the first category *(table 3)*. By applying the analysis mentioned on p. 684 to these figures, it can be shown that water-table depth and calcium content influence the distribution of Ragwort to the same extent (p-values, see below).

$p_1^W = 1.48$ $p_1^C = 1.48$
$p_2^W = 0.93$ $p_2^C = 0.88$
$p_3^W = 0.84$

In the category "predominantly calcareous plus water-table depth > 100 cm", *S. jacobaea* was observed in 96% of the squares, a much higher percentage than was found in any one of the categories in which the squares were divided based on the separate soil properties. This very high percentage indicates that the combination of calcium content and water-table depth gives a good description of the distribution of *S. jacobaea.*

Table 3. Distribution of Ragwort in relation to calcium content of the soil and water-table depth.

	predominantly calcareous		predominantly non-calcareous		total	
water-table depth	squares present	squares with Ragwort	sp	sR	sp	sR
0–20	9	3 (33%)	233	80 (34%)	242	83 (34%)
20–100	362	234 (65%)	919	341 (37%)	1281	575 (45%)
>100	85	82 (96%)	239	147 (62%)	324	229 (71%)
total	456	319 (70%)	1391	568 (41%)	1847	887 (48%)

χ^2 calcium content – Ragwort: 19.77; $p < 0.005$

3. SOIL DRAINAGE AND DISTRIBUTION OF THE CINNABAR MOTH

The main consumer of Ragwort, the Cinnabar Moth, is also found throughout The Netherlands *(fig. 2,* data from LEMPKE (1961), supplemented with records recently compiled by him and kindly put at my disposal). As regards numbers, the insect appears to occur mainly in the dunes (Lempke, pers. comm.).

DEMPSTER (1971) compared the distribution of *T. jacobaeae* in England and

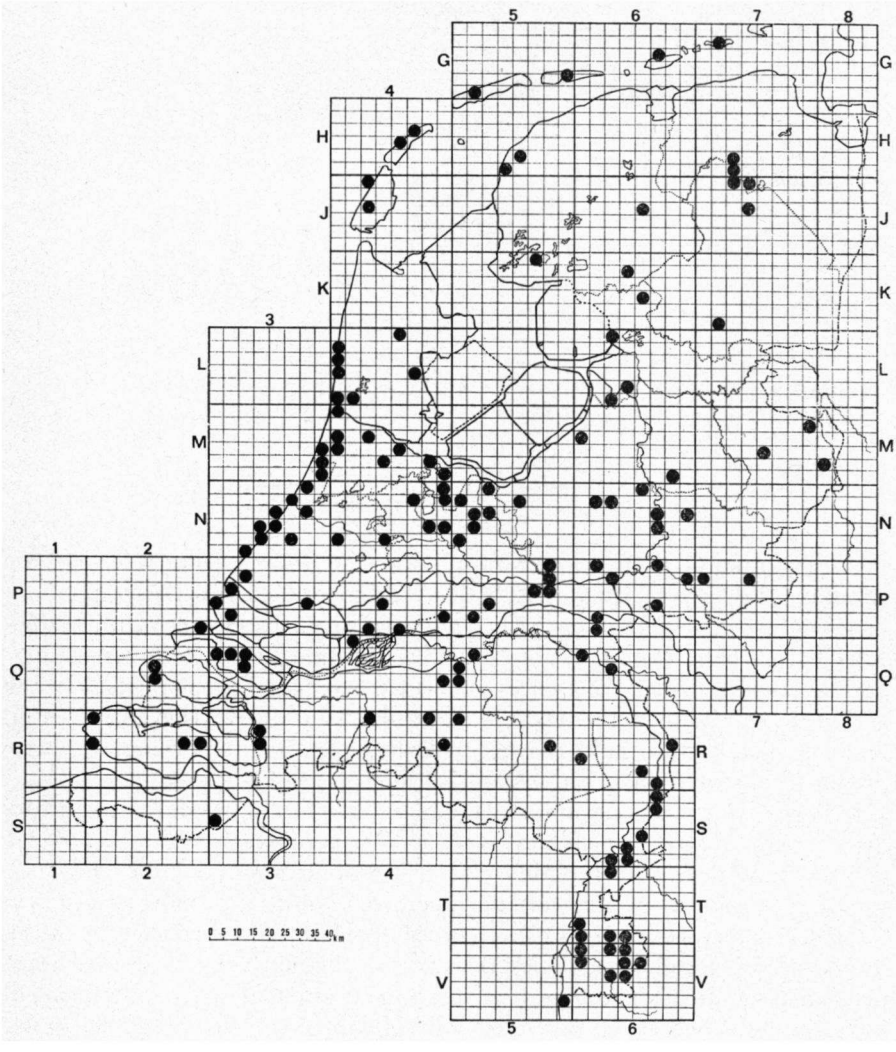

Fig. 2. Distribution of *Tyria jacobaeae* L. in The Netherlands.

Wales with the degree of drainage (in squares of 100 km²) and found it scarce in areas with poor drainage (in squares on well drained soils: 39.4%; moderately drained: 33.9%; poorly drained: 19.4%). He explained the distribution of the moth by the inability of the pupa, which winters in a loose cocoon in contact with the soil, to survive extremely moist conditions (contact with water).

Although in The Netherlands the percentages of squares with *Tyria* on the wetter soils are also slightly less than on the dry soils, the differences are not significant, neither for the situation in which an overall comparison is made of

Table 4. Distribution of the Cinnabar Moth in relation to drainage of the soil.

	number of squares				
	present	with *Tyria jacobaeae*	expected with *Tyria jacobaeae*	χ^2	p
a. distribution over all hour-squares					
poorly drained	251	19 (7.6%)	18.9		
moderately drained	495	27 (5.5%)	37.3	5.70	≈0.13
well-drained	693	53 (7.7%)	52.2		
very well-drained	407	40 (9.8%)	30.6		
b. distribution over hour-squares with Ragwort					
poorly drained	89	10 (11.2%)	11.1		
moderately drained	180	16 (8.9%)	22.5	4.12	≈0.25
well-drained	392	49 (12.5%)	49.0		
very well-drained	219	35 (16.0%)	27.4		

the distribution of *T. jacobaeae* with soil drainage *(table 4a)* nor when the distribution of the moth is compared with soil drainage only over those squares in which Ragwort was found to occur *(table 4b)*. This distinction was made because Ragwort, as shown, is not randomly distributed over the different categories of soil drainage. Differences in occurrence of the Cinnabar Moth in the various categories therefore might be due to Ragwort distribution. Apparently, on the grid scale used, the degree of soil drainage is not of importance for interpreting the distribution of *T. jacobaeae* in The Netherlands.

However, when comparing populations of the moth in dry and moist areas, there is another factor which must be taken into account, viz. the local population area and density of the food plant. Two observations support this idea. Firstly, populations of Ragwort in dune areas (which generally have a low water level) may cover areas of several hundreds of square meters in rather high densities; locally, population density may amount even up to 30 mature plants and hundreds of seedlings per m^2. Similar populations are not normally found in the inland areas. Out of 99 squares lying completely or partly in the coastal dune area (almost all in the category very well drained soils + water-table depth > 100 cm) 91 (92%) contain sites on which Ragwort grows and in 28 of these (31%) the Cinnabar Moth was observed. These percentages are much higher than the overall percentages on the dry soils. Secondly, in our dune study area, Mrs. M. Eggenkamp and Miss. M. Kruyt, who examined 93 samples (of 4 m^2 each) from Ragwort populations *(table 5)* found that in the category "large population area + large population cover" the percentage of samples with Cinnabar Moth eggs was much higher than in the other categories. Unfortunately these data cannot yet give decisive evidence since the local population density of the moth and therewith the chance of finding eggs may fluctuate heavily. We will continue research on this point.

Table 5. The presence of Cinnabar Moth eggs in 93 samples (of 4 m^2 each) in relation to Ragwort population size and cover.

population cover	population area			
	< 250 m^2 samples		> 250 m^2 samples	
	total number	number with eggs	total number	number with eggs
< 15%	22	4 (18%)	19	1 (5%)
⩾ 15%	20	5 (25%)	32	19 (59%)

4. CONSUMER-FOODPLANT RELATION

The Cinnabar Moth is mentioned from 150 out of 1874 hour squares in The Netherlands (of the IJsselmeerpolders only the Noord-Oost-polder has been included). Over three quarters (117) of the moth's records coincide with a record of Ragwort, whereas 30 other squares with *T. jacobaeae* are adjoining to one or more squares in which Ragwort was observed. Thus only three records of *T. jacobaeae* came from sites that are not in the immediate vicinity of a square in which Ragwort was found to occur. Although caterpillars of the Cinnabar Moth have been shown to feed on *Tussilago farfara* L. (Mrs. Blokpoel, 1964, typewritten report), *Senecio vulgaris* L. (CAMERON 1935), *Senecio aquaticus* Hill (LEMPKE 1961), the data presented give an indication of the strong ties of this moth to Ragwort. From the literature it appears that observations of the moth far away from its food plant are rare. However, some captures on light vessels, mentioned by WILLIAMS *et al.* (1942) (35 and 48 km off the British east coast) and by Lempke (1962) (50 km off the Belgian west coast) show that this cannot be due to a small dispersal capacity.

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REFERENCES

ATLAS VAN NEDERLAND (1961): Governmental Printing and Publishing Office, The Hague.
CAMERON, E. (1935): A study of the natural control of Ragwort. *J. Ecol.* **23**: 265–322.
DEMPSTER, J. P. (1971): The population ecology of the Cinnabar Moth, Tyria jacobaeae L. (Lepidoptera, Arctiidae). *Oecologia (Berl.)* **7**: 26–67.

HARPER, J. L. & W. A. WOOD (1957): Biological flora of the British Isles – Senecio jacobaea L. *J. Ecol.* **45**: 617–637.

LEMPKE, B. J. (1961): Catalogus der Nederlandse Macrolepidoptera (8e suppl.). *Tijdschr. Entom.* **104**: 111–186.

LEMPKE, B. J. (1962): Insecten gevangen op het lichtschip "Noord Hinder". *Ent. Ber., Amst.* **22**: 101–111.

MENNEMA, J. (in prep.): Atlas van de Nederlandse flora.

SCHEFFÉ, H. (1964): *The analysis of variance.* John Wiley & Sons. New York. 4th ed.

VINK, A. P. A. & E. J. VAN ZUILEN (red.) (1967): *De geschiktheid van Nederland voor akker- en weidebouw.* Toelichting bij de: Zeer globale bodemgeschiktheidskaart voor akker- en weidebouw van Nederland. Stichting voor Bodemkartering (Soil Survey Institute), Wageningen.

WILLIAMS, C. B., G. F. COCKBILL, M. E. GIBBS & J. A. DOWNES (1942): Studies in the migration of Lepidoptera. *Trans. R. ent. Soc. London* **92**: 101–283.