GROWTH OF MICROSPECIES OF DIFFERENT SECTIONS OF TARAXACUM IN CLIMATIC CHAMBERS.

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SUMMARY

Growth characteristics of 13 microspecies of *Taraxacum* have been studied in climatic chambers during the 3rd, 4th and 5th week after germination by weekly recording the production of root and shoot biomass at three different temperatures.

Of all plants harvested the results of the measurements of dry weight, root/shoot ratios, leaf areas, number of leaves, leaf area ratios, specific leaf areas and relative growth rates are given and discussed in relation to the section, the ploidy level and the habitat of the microspecies. In general, microspecies of the sections *Taraxacum* and *Hamata,* originating from productive environments show a high biomass production and large leaf areas. They form relatively few but large leaves. Microspecies of the sections *Spectabilia* and *Palustria* from low-productive environments have a low biomass production and small leaf areas. They bear relatively small leaves. So a correlation between growth characteristics and the nutritional potential of the habitat was established, which may be partly interpreted as indicative of an adaptation.

1. INTRODUCTION

In The Netherlands dandelions are very common and represented by six sections (HAGENDIJK et al. 1975, 1982, ØLLGAARD 1983). The section *Obliqua* (with a single microspecies) is restricted in its occurrence to the coastal area. The section *Erythrosperma* (23 microspecies) is found both along the coast and in the interior. These two sections are found in open grassland vegetation on dry and mostly humic, sandy soils. The sections *Palustria* (10 microspecies) and *Spectabilia* (9 microspecies) are rare and prefer unfertilized, wet grasslands. The sections *Hamata* (17 microspecies) and *Taraxacum* (136 microspecies) are very common throughout the country in meadows, roadsides, lawns and trodden places.

Since the Dutch microspecies of *Taraxacum* have only recently been treated taxonomically, ecological data concerning the microspecies are scarce (for a survey, see STERK et al. 1983).

A characteristic feature of *Taraxacum* is the great number of microspecies that have been distinguished, especially in section *Taraxacum,* which is connected with the supposedly predominant agamospermous mode of reproduction. However, recent investigations have shown that in the section *Taraxacum* sexuality is of frequent occurrence in Western and Central Europa (DEN NIJS & STERK 1980, 1984) and sexual individuals in triploid (asexual) populations have been recorded also from several localities in The Netherlands (STERK et

al. 1982, ROETMAN, DEN NIJS & STERK, in prep.) This incidence of sexuality
has a fundamental bearing upon the taxonomy and the ecological identity of
the microspecies concerned.

The great number of described microspecies poses the problem whether the
over 150 microspecies of sections *Hamata* and *Taraxacum* occupy different
niches within the restricted ecological ranges of both sections or that they all,
or groupwise, represent ecological equivalents and thus share the same niche
or niches.

In the latter case the actual distribution of the microspecies in nature is to
a great extent determined by historical events and by an *at random* dispersal.
In literature it is suggested that the microspecies are ecologically finely tuned
to their environments (HOFSTEN 1954, FORD 1981a, 1981b, LOENHOUD & DUYTS
1981, OOSTERVELD 1983). According to SOLBRIG & SIMPSON (1974, 1977) differ-
ent biotypes of section *Taraxacum* from various habitats occupy different posi-
tions in the r- and K-continuum, but according to ØLLGAARD (1983) the ecology
of the *Hamata* group is rather similar to that of the weedy section *Taraxacum*.

The ecological differentiation of the microspecies of *Taraxacum* in The Neth-
erlands has been investigated by STERK et al. (1983), who suggested that the
microspecies exhibit appreciable ecological differences. The outcome of these
field studies rendered it possible to distinguish between microspecies with a wide
ecological amplitude and those showing a narrower range.

Recently much attention has been paid to growth analyses under controlled
conditions and to their ecological significance (EVANS 1972, HUNT 1978, GRIME
& HUNT 1975, GRIME 1979, VAN ANDEL & JAGER 1981, BOSTOCK & BENTON
1979, VAN ANDEL et al. 1984). Growth parameters of closely related species
may be different, and thus of adaptive significance (HUNT 1978, EVANS 1972).

In the present paper the results of an investigation into the growth of 13 micro-
species of *Taraxacum* in climatic rooms are discussed. These microspecies belong
to different sections and originate from various geographical areas and ecologi-
cal sites in Europe.

2. MATERIALS AND METHODS

2.1. Microspecies
Table 1 lists the microspecies studied and provides data concerning their taxono-
my, origin and ecology, and also states the ploidy-level of the parent plants.
Most plants were raised from seeds of plants growing in the experimental garden.
The parent plants came from natural populations. The sexual diploids were
grown from hybrid seed obtained by crossing plants originating from the same
natural population. For the nomenclature see HAGENDIJK et al. (1975, 1982)
and JENNISKENS (1984).

2.2. Growth conditions, sampling methods and measurements
Prior to each experiment the mean achene weights were determined by weighing
1000 air-dried seeds.

Table 1. The taxonomy, geography, ecology and ploidy-level of the microspecies used.
eg = extensively grazed, hf = heavily fertilized, ig = intensively grazed, lf = lightly fertilized,
mf = moderately fertilized, n = nature reserve, nd = no dunging, pa = pasture, ug = ungrazed.
(1) = related to *T. quadrangulum*, (2) = related to *T. paradoxachrum*.

Section	Microspecies	Nr.	Origin	Ecology	Ploidy level
Erythrosperma	T. taeniatum	TH11	Netherlands	n,ug,fa	3x
Hamata	T. lancidens	Tx	Netherlands	pa,eg,mf	3x
Palustria	T. hollandicum	T50	Netherlands	pa,eg,mf	3x
Spectabilia	T. hygrophylum	T408	Netherlands	pa,eg,lf	3x
Spectabilia	T. nordstedtii	T420	Netherlands	pa,eg,lf	6x
Taraxacum	T. adamii	T16	Netherlands	pa,eg,lf	3x
Taraxacum	T. ancistrolobum	T20	Netherlands	pa,ig,hf	3x
Taraxacum	T. ekmanii	T323	Netherlands	pa,ig,hf	3x
Taraxacum	T. limburgense	TMJ79	Netherlands	pa,ug,nd	2x
Taraxacum	T. raunkiaeri	T78	Netherlands	pa,eg,mf	3x
Taraxacum	T. sellandii	T72	Netherlands	pa,ig,hf	3x
Taraxacum	T. Unidentified (1)	THL33	Switzerland St.Gallen, 750 m alt.	pa,eg,hf	2x
Taraxacum	T. Unidentified (2)	TPP23	S.Germany, 600 m alt.	pa,ug,hf	2x

Seeds of the thirteen microspecies, enumerated in *table 1,* were sown at 15–20 °C in ceramic containers filled with steamed soil. From 6.00 a.m.–18.00 p.m. two 40 W incandescent light bulbs at a distance of 20 cm above the container provided a constant illumination to supplement the daylight during March and April 1983. Fourteen days after germination the seedlings were planted separately in 10 cm diameter plastic pots filled with well-mixed and sieved, fine humic dune sand from the "Noordhollands Duinreservaat" and placed in a glass house. After one week 0.3 g "Pokon fertilizer" (15% N, 20% P and 25% K) enriched with micronutrients (Mn, Zn, Cu, Mb, and Bo) was added to each pot. After a two weeks' stay in the glasshouse, the young plants with about five small leaves (including the two cotyledons) were divided in lots that were placed in three climatic chambers at a temperature of 13 °C (day) and 10 °C (night), a temperature of 18 °C (day) and 15 °C (night), and at a temperature of 23 °C (day) and 20 °C (night) respectively.

In all rooms, the daily photoperiod lasted from 5.00 a.m.–21.00 p.m. and the light intensity and relative humidity was kept at 7000 lux and 85%, respectively. Every third day the plants were watered.

From each microspecies four groups of ten plants each were harvested. The first harvest was just before entering the climatic chamber, the 2nd, 3rd and 4th harvest after a stay in the climatic rooms of 1, 2 and 3 weeks respectively.

The roots were subsequently washed clean in slowly streaming water. Finally each plant was blotted and all its leaves were removed, which were placed together with the roots between sheets of drying paper and kept for seven days in a ventilated furnace at 40 °C. The dry weights of root and shoot were separately determined on a microbalance. It was not possible to separate the very short

stem from the root and, therefore, the stem and the roots were weighed together. After the specimens had been oven-dried, leaf areas were measured with a Licor portable area meter, model L1-3000.

At least 95% of the values of the parameters recorded after a stay of 3 weeks in the climatic chambers could be attributed the growth in the climatic rooms. Therefore these are directly associated with the conditions in the climatic rooms and not with the growth of the first two weeks.

As the first step in the analysis of the variance of the means of the samples the Kruskal-Wallis test was used. After demonstrating the presence of significant heterogenity the Least Significant Difference test was used (95% confidence levels) (SOKAL & ROHLF 1969). For formulae used for Leaf Area Ratio (LAR), Specific Leaf Area (SLA) and Leaf Weight Ratio (LWR) see HUNT (1978), for Relative Growth Rate (RGR) see VENUS & CAUSTON 1979).

Of the ten harvested plants of each microspecies the mean values were consistenly calculated and from these the mean values for a three weeks period in the climatic rooms were determined (indicated by the line above the expression: *e.g.*, LAR → $\overline{\text{LAR}}$, RGR → $\overline{\text{R}}$).

3. RESULTS

3.1. Dry matter production (DMP)

In *fig. 1* an overview is given of the average dry matter production (in mg per plant), after three weeks of growth in climatic chambers at three different temperature ranges.
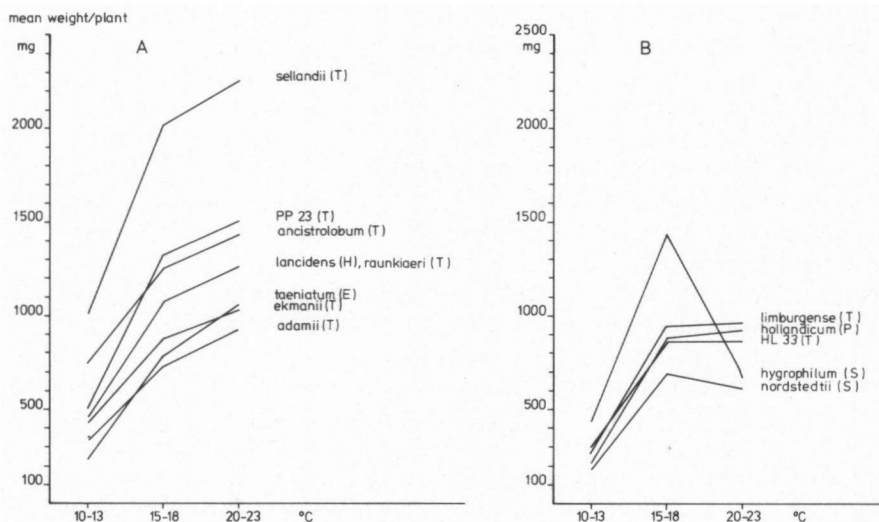

Fig. 1. Mean dry matter production in mg per plant of 13 microspecies of *Taraxacum* at 3 temperature ranges. E = sect. *Erythrosperma* H = sect. *Hamata*, P = sect. *Palustria*, S = sect. *Spectabilia*, T = sect. *Taraxacum*.

Table 2. Differences in mean dry matter production at 20–23 °C between pairs of taxa subjected to this condition. + = significant, − = not significant.

	T. sellandii	T. PP23	T. ancistrolobum	T. raunkiaeri	T. lancidens	T. ekmanii	T. taeniatum	T. limburgense	T. adamii	T. hollandicum	T. HL33	T. hygrophilum	T. nordstedtii
T. sellandii		+	+	+	+	+	+	+	+	+	+	+	+
T. PP23			−	−	−	+	+	+	+	+	+	+	+
T. ancistrolobum				−	−	+	+	+	+	+	+	+	+
T. raunkiaeri					−	−	−	+	+	+	+	+	+
T. lancidens						−	−	+	+	+	+	+	+
T. ekmanii							−	−	−	−	−	+	+
T. taeniatum								−	−	−	−	+	+
T. limburgense									−	−	−	+	+
T. adamii										−	−	+	+
T. hollandicum											−	−	+
T. HL33												−	+
T. hygrophilum													−
T. nordstedtii													

The DMP values showed the greatest differences, sometimes of over 350%, in the experiments at 20–23 °C. Microspecies of the sect. *Taraxacum* produced the greatest quantities of biomass, but also in this group there are appreciable differences, of up to about 37% of the biomass of the most productive species *T. sellandii*.

Table 2 shows that most of the pairs of microspecies of the sect. *Taraxacum* differed significantly in their dry matter production.

Comparison of the dry matter production at three temperature ranges permits the distinction of three groups of microspecies *viz.*:

1. Microspecies exhibiting a continually increasing dry matter production at rising temperatures (*fig. 1A*), the increase from the 10–13 °C range to the 15–18 °C range being the greatest and varying from 165% to 330%, that from the 15°–18°C range to the 20–23 °C one is smaller and varies from 110% to 140%. This group comprises especially triploid, agamospermous microspecies of the sect. *Taraxacum*, but *T. taeniatum* (sect. *Erythrosperma*) and *T. lancidens* (sect. *Hamata*) also belong to this assembly.

2. Microspecies exhibiting a marked increase in dry matter production from the 10–13 °C range to the 15–18 °C one, but no further increase when grown at 20–23 °C (*fig. 1B*). This group comprises microspecies of the sections *Spectabilia* and *Palustria* and in addition two microspecies of the sect. *Taraxacum*. In most cases the biomass production is markedly lower in comparison with the first group, at any rate in the ranges 10–13 °C and 20–23 °C.

3. The microspecies *T. hygrophilum* with the highest dry matter production in the 15–18 °C range and a markedly lower one in the 10–13 °C and 20–23 °C ranges (*fig. 1B*).

Table 3. Values of the mean Relative Growth Rate (mg·mg·week^{-1}) of 13 microspecies of *Taraxacum* at three temperature ranges as compared with the mean weight of the achenes and the mean dry weight per plant at the time of the first and the fourth harvest.

Microspecies	Sect.	Mean Relative Growth Rate			Mean weight achenes in mg	Mean dry weight per plant in mg 1st harvest	Mean dry weight per plant in mg 4th harvest 20–23°C	Mean increase in mg dry weight 20–23°C
		20–23°C	15–18°C	10–13°C				
T. raunkiaeri	T	1,78	1,85	1,47	0,49	9	1281	1272
T. taeniatum	E	1,48	1,39	0,99	0,33	13	1028	1015
T. lancidens	H	1,40	1,35	1,06	0,63	22	1271	1249
T. limburgense	T	1,35	1,35	0,93	0,46	17	962	945
T. adamii	T	1,34	1,26	1,01	0,60	19	938	919
T. sellandii	T	1.30	1,26	1,03	0,81	46	2257	2211
T. ancistrolobum	T	1,30	1,22	1,07	0,78	32	1430	1398
T. ekmanii	T	1,21	1,11	0,89	0,72	31	1042	1011
T. HL33	T	1,18	1,17	0,82	0,91	27	871	844
T. PP23	T	1,09	1,04	0,70	0,96	55	1504	1449
T. nordstedtii	S	1,05	1,10	0,65	0,65	25	605	580
T. hollandicum	P	1,00	0,98	0,55	0,70	45	915	870
T. hygrophilum	S	0,82	1,10	0,70	0,78	53	676	623

3.2. The relative growth rate (RGR)

The recorded mean relative growth rate (mg.mg.week^{-1}) of the microspecies studied at the three temperature ranges are given in *table 3*.

At 20–30 °C there are clear differences between the mean RGRs of the microspecies at the top and those at the base of the range. Of the intermediate ones the R̄ changes more of less gradually. *T. raunkiaeri, T. taeniatum, T. lancidens* and the diploid *T. limburgense* showed the highest R̄ values. Especially the high R̄ of *T. taeniatum*, which species in nature forms only small plants, is striking. The lowest values are found in species of *Spectabilia* and *Palustria*. Also *T. ekmanii* and the non-Dutch microspecies of the sect. *Taraxacum* THL33 and TPP23 do not score highly.

The significance of the differences between pairs of microspecies is given in *table 4*.

The differences in the RGR-values are not simply proportional to the size of the production of biomass (*table 3*). Upon the whole the microspecies with low RGR-values also have a low biomass production, but there are exceptions (TPP23). Microspecies with the highest values of biomass production do not necessarily also have the highest RGR but may show an average RGR (*T. sellandii* and *T. ancistrolobum*).

The mean RGR, as measured in the climatic room, is related to the weight the plants had at the time of the first harvest, before they were transferred to the climatic room; this value is often correlated with the weight of the achenes. Generally speaking the microspecies with a low weight at the time of the first

Table 4. Differences in mean Relative Growth Rate at 20–23 °C between pairs of microspecies.
+ = significant, − = not significant.

	T. raunkiaeri	T. taeniatum	T. lancidens	T. limburgense	T. adamii	T. sellandii	T. ancistrolobum	T. ekmanii	T. HL33	T. PP23	T. nordstedtii	T. hollandicum	T. hygrophilum
T. raunkiaeri		+	+	+	+	+	+	+	+	+	+	+	+
T. taeniatum			−	+	−	+	+	+	+	+	+	+	+
T. lancidens				−	−	−	−	+	+	+	+	+	+
T. limburgense					−	−	−	−	+	+	+	+	+
T. adamii						−	−	−	−	+	+	+	+
T. sellandii							−	−	−	+	+	+	+
T. ancistrolobum								−	−	+	+	+	+
T. ekmanii									−	−	−	+	+
T. HL33										−	−	+	+
T. PP23											−	−	+
T. nordstedtii												−	+
T. hollandicum													+
T. hygrophylum													

harvest have a high RGR whereas microspecies with high weights at the first harvest time have a low RGR. However, there are exceptions (compare THL33 from Switzerland with TPP23 from southern Germany). Neither is there always a consistent correlation with the achene weight and the weight at the time of the first harvest. Like *T. adamii*, *T. lancidens* exhibits a relatively high achene weight and a low weight at the first harvest. This may be attributable, among other things, to an accidental selection of relatively small seedlings for further investigation (with respect to the achene weights).

As might be expected, all microspecies have the lowest R at the lowest temperature. The differences in $\bar{R}$ between 10–13 °C and 15–18 °C are without exception rather great, whereas those between 15–18 °C and 20–23 °C are smaller. In *T. taeniatum* (sect. *Ervthrosverma*) $\bar{R}$ increases more strongly than in the other taxa. *T. hygrophilum* (sect. *Spectabilia*) has the highest $\bar{R}$ at 15–18 °C and also attains the greatest biomass production in this temperature range. The $\bar{R}$ per day was highest in nearly all species when measured in the first week in the climatic room kept at 15–18 °C

3.3. Leaf area (LAR)

In *fig. 2* the mean leaf area per plant is given. It appears that there are appreciable differences in leaf surface area. Comparisons of pairs of microspecies mostly yield statistically significant differences (see *table 5*). As might be expected the differences appear to be correlated with the biomass production (see *fig. 3*). The smallest leaf areas were found in the microspecies of sect. *Spectabilia*, somewhat larger ones in a small group of microspecies among which a taxon of sect. *Palus-*

Fig. 2. Mean leaf area per plant in cm^2 of 13 microspecies of *Taraxacum* grown at three temperature ranges.

tria, one of sect. *Erythrosperma*, two diploid and two triploid ones of sect. *Taraxacum*. *T. lancidens* (sect. *Hamata*) and *T. raunkiaeri* (sect. *Taraxacum*) scored a little below the average in the range of microspecies studied. Four species of sect. *Taraxacum* with the greatest biomass also had the largest leaves.

Table 5. Differences in mean leaf areas between pairs of microspecies grown at 20–23 °C. + = significant, − = not significant.

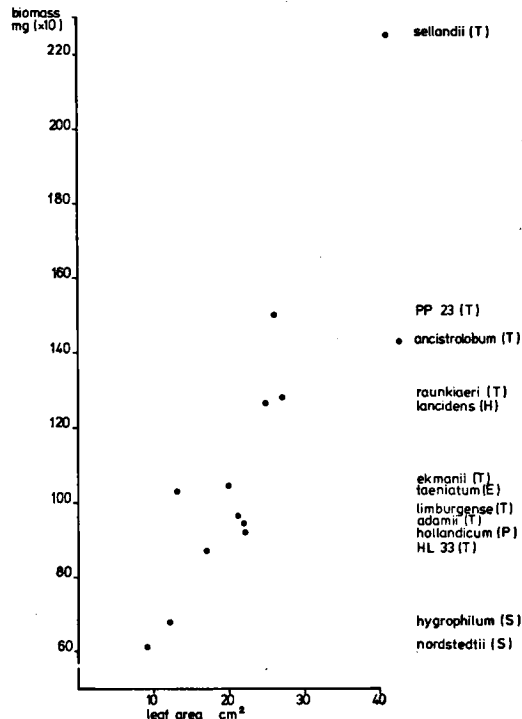| *	T. ancistrolobum	T. sellandii	T. raunkiaeri	T. PP23	T. lancidens	T. adamii	T. hollandicum	T. limburgense	T. ekmanii	T. HL33	T. taeniatum	T. hygrophilum	T. nordstedtii
T. ancistrolobum	−	+	+	+	+	+	+	+	+	+	+	+
T. sellandii		+	+	+	+	+	+	+	+	+	+	+
T. raunkiaeri			−	−	+	+	+	+	+	+	+	+
T. PP23				−	−	−	+	+	+	+	+	+
T. lancidens					−	−	−	−	+	+	+	+
T. adamii						−	−	−	+	+	+	+
T. hollandicum							−	−	+	+	+	+
T. limburgense								−	−	+	+	+
T. ekmanii									−	+	+	+
T. HL33										−	+	+
T. taeniatum											−	−
T. hygrophilum												−
T. nordstedtii													

Fig. 3. Relation between biomass and leaf area in 13 microspecies of *Taraxacum* grown at 20–23 °C.

A comparison of the mean leaf areas per plant produced at the three temperature trajects permits the distinction of three groups of microspecies:
1. Microspecies in which the average leaf area increases with a rising temperature. Most of the taxa studied belong to this group.
2. Microspecies in which the leaf size of plants grown at 20–23 °C is not much larger than that of plants grown at 15–18 °C, e.g. *T. taeniatum* and *T. nordstedtii*. Among the taxa studied, these have the smallest mean leaf areas.
3. The microspecies *T. hygrophilum*, which produces the largest leaves at 15–18 °C and smaller leaves at the other temperature ranges.

3.4. Number of leaves per plant, average leaf area per plant and mean surface area of leaves
In *table 6* for three temperature ranges the mean number of leaves per plant and the mean leaf surface area per plant and the average leaf surface area is given.

It appears that there can be appreciable differences in the mean number of leaves per plant. *Table 7* shows that these differences may be significant ($+$) or not so ($-$). The number of leaves per plant is not correlated with the total leaf surface area of the plant. In the microspecies TPP23 the leaf area per plant

Table 6. Mean number of leaves per plant (N.L.), average leaf area per plant (L.S.) and the mean leaf surface (S.L.) of 13 microspecies of *Taraxacum* in three temperature ranges.

Microspecies	Sect.	20–23 °C			15–18 °C			10–13 °C		
		N.L.	L.S.	S.L.	N.L.	L.S.	S.L.	N.L.	L.S.	S.L.
T. raunkiaeri	T	21	271	12.9	27	153	5.7	19	54	2.8
T. hollandicum	P	20	216	10.8	13	82	6.3	13	39	3.0
T. limburgense	T	18	211	11.7	22	131	6.0	14	30	2.1
T. hygrophilum	S	16	118	7.4	21	166	7.9	11	51	4.6
T. lancidens	H	15	245	16.3	14	89	6.4	11	55	5.0
T. ancistrolobum	T	15	422	28.1	12	165	13.8	13	96	7.4
T. ekmanii	T	14	205	14.6	17	107	6.3	18	77	4.3
T. sellandii	T	14	413	29.5	13	230	17.7	13	124	9.5
T. adamii	T	14	221	15.8	14	120	8.6	11	40	3.6
T. taeniatum	E	13	134	10.3	19	105	5.5	13	38	2.9
T. PP23	T	12	258	21.5	14	198	14.1	12	77	6.4
T. nordstedtii	S	12	92	7.7	14	82	5.9	12	34	2.8
T. HL33	T	11	170	15.5	13	103	7.9	11	49	4.5

(L.S.), does not differ very much from that of *T. raunkiaeri,* but the number of leaves per plant is clearly different: in *T. raunkiaeri* the total leaf area per plant is from a relatively great number of small leaves whereas in TPP23 it is from fewer but larger leaves. The copiously biomass-producing microspecies *T. sellandii* and *T. ancistrolobum* attain their high dry matter production by the action of only a relatively small number of leaves. The much more slowly grow-

Table 7. Differences in mean number of leaves per plant grown at 20–23 °C.
+ = significant, − = not significant.

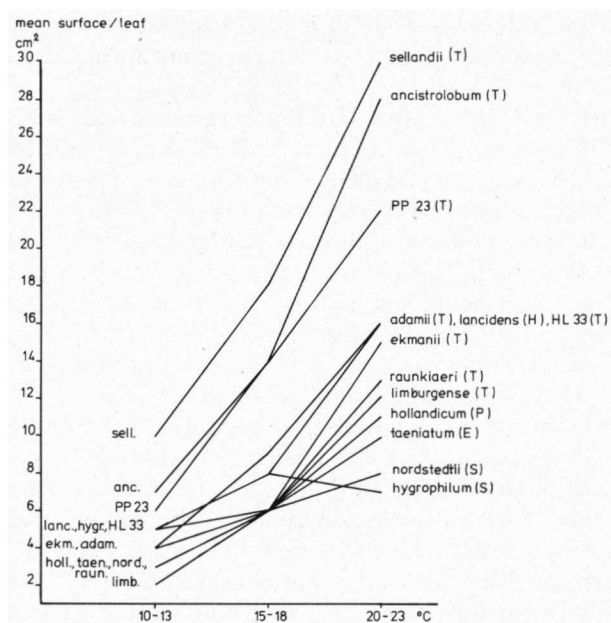|	T. raunkiaeri	T. hollandicum	T. limburgense	T. hygrophilum	T. lancidens	T. ancistrolobum	T. ekmanii	T. sellandii	T. adamii	T. taeniatum	T. PP23	T. nordstedtii	T. HL33
T. raunkiaeri		−	−	+	+	+	+	+	+	+	+	+	+
T. hollandicum			−	+	+	+	+	+	+	+	+	+	+
T. limburgense				−	+	+	+	+	+	+	+	+	+
T. hygrophilum					−	−	−	−	−	−	+	+	+
T. lancidens						−	−	−	−	−	−	+	+
T. ancistrolobum							−	−	−	−	−	−	+
T. ekmanii								−	−	−	−	−	+
T. sellandii									−	−	−	−	+
T. adamii										−	−	−	+
T. taeniatum											−	−	−
T. PP23												−	−
T. nordstedtii													−
T. HL33													

Fig. 4. Mean surface per leaf in cm^2 of 13 microspecies of *Taraxacum* in three temperature ranges.

ing diploid microspecies *T. limburgense* attains its much smaller leaf area and growth rate by the action of more and smaller leaves per plant as compared to *T. sellandii*. From *table 6* it appears that within the section *Taraxacum* there is an appreciable variation between the microspecies as regards the growth strategy, if the relation number of leaves per plant, size of the leaves and the total leaf area per plant are being taken into account. The same holds for the *Spectabilia*.

The majority of the microspecies show a strong rise of the average surface per leaf at higher temperatures (see *fig. 4*). In most of the microspecies the increment varies at both temperature-transitions with a factor of about × 1.5 to × 2.0. *T. hygrophilum* (sect. *Spectabilia*) is clearly an exception by showing a slight decrease of the mean leaf surface area at the transition from 15–18 °C to 20–23 °C. In some taxa the number of leaves per plant increases going from 10–13 °C to 15–18 °C to decrease again in the next temperature range (*T. raunkiaeri, T. limburgense* and *T. hygrophilum*), see *table 6*.

In other microspecies there hardly is a rise (*T. sellandii* and *T. nordstedtii*), but *T. ekmanii* at higher temperature tends to make fewer leaves per plant. The continuous increase of the mean leaf surface area per plant is, therefore, attributable to different components operative in the different temperature range (compare *fig. 2*). In the fastest growing species *T. sellandii* and *T. ancistrolobum* the increase in mean leaf surface area per plant is mainly caused by an increase

in size of the individual leaves at all higher temperature ranges; but in other species changes in the mean number of leaves per plant are of greater importance.

3.5. The leaf area ratio, specific leaf area and leaf weight ratio

In *table 8* of 13 microspecies at 20–23 °C $\overline{\text{LAR}}$, $\overline{\text{SLA}}$ and $\overline{\text{LWR}}$ over the period in the climatic room are plotted against the dry matter production and the increase of dry matter production after three weeks of growth in the climatic room. The LAR gives some indication of the relation between the photosynthetic tissue and the total of respiring tissues of the plant. From the table it appears that the faster growing species of the section *Taraxacum*, with the highest production of biomass, are among the uppermost in the table. In the lower region we find the more slowly growing taxa of the same section and of sections *Spectabilia*, *Palustria* and *Erythrosperma*. The diploid *T. limburgense* (sect. *Taraxacum*) is exceptional in that it has a relatively low production of biomass, but a high $\overline{\text{LAR}}$ value. Because a high $\overline{\text{LAR}}$ is related to a high $\overline{\text{LWR}}$, this means that the microspecies produces a relatively great amount of leafy matter.

In general, high LAR values usually coincide with high SLA values and low LAR values with low SLA values. A high SLA value indicates that the leaf is relatively thin and a low SLA value that the leaf is relatively thick. The microspecies *T. adamii* (sect. *Taraxacum*), *T. hollandicum* (sect. *Palustria*) and *T. nordstedtii* (sect. *Spectabilia*) – all microspecies with a low production of biomass – have relatively thick leaves. Taxa showing a high production of biomass have relatively thin leaves; they mostly belong to the section *Taraxacum*.

There are clear differences between the mean LWR of certain of microspecies studied. *T. nordstedtii*, TPP23 and *T. raunkiaeri*, for instance, have a low LWR and produce a relatively high amount of rootweight. *T. raunkiaeri* has the high-

Table 8. The mean values of Leaf Area Ratio, Specific Leaf Area and Leaf Weight Ratio plotted against the mean dry matter production and the increase of dry matter production after three weeks of growth in the climatic room of 13 microspecies of *Taraxacum* at 20–23 °C.

Microspecies	Sect.	$\overline{\text{LAR}}$	$\overline{\text{SLA}}$	$\overline{\text{LWR}}$	Mean dry weight in mg 4th harvest	Increase in dry weight
T. ancistrolobum	T	0.31	0.42	0.74	1430	1398
T. raunkiaeri	T	0.30	0.50	0.61	1281	1272
T. sellandii	T	0.26	0.44	0.65	2257	2211
T. limburgense	T	0.25	0.35	0.72	962	945
T. lancidens	H	0.21	0.31	0.67	1271	1249
T. PP23	T	0.20	0.32	0.59	1504	1449
T. HL33	T	0.20	0.29	0.69	871	844
T. ekmanii	T	0.19	0.30	0.63	1042	1011
T. hygrophilum	S	0.19	0.30	0.63	676	623
T. adamii	T	0.18	0.28	0.64	938	919
T. hollandicum	P	0.18	0.26	0.69	915	870
T. taeniatum	E	0.18	0.29	0.63	1028	1015
T. nordstedtii	S	0.15	0.28	0.57	605	580

est $\overline{SLA}$, forms the thinnest leaves and, the low $\overline{LWR}$ notwithstanding, attains a high $\overline{LAR}$. *T. ancistrolobum, T. limburgense,* THL33 and *T. hollandicum* have a high $\overline{LWR}$. These taxa, therefore, produce a relatively large amount of leafy matter. There is a fair amount of microspecies that do not differ much in their $\overline{LWR}$ or only slightly so.

4. DISCUSSION AND CONCLUSIONS
4.1. Growth characters and ecology of polyploid agamospermous microspecies of several sections

In *table 9* the most important growth characteristics recorded are roughly related to what is known of the ecology of the taxa studied. The ecological data are borrowed from HAGENDIJK et al. (1975, 1982) and from STERK et al. (1983). The productivity of the environment is related to the grazing and fertilizing regime. Grasslands strongly fertilized and grazed by cattle are here considered to belong to the productive environments, but grasslands that are not or but lightly fertilized and grazed and undunged hay fields (grazed after hay-making or not so) are considered here to belong to the low-productive environments.

From the table it appears that some microspecies are characteristic of productive environments and other ones of non-productive ones, with a sizeable intermediate group. As far as the microspecies *T. sellandii, T. ancistrolobum, T. adamii* (sect. *Taraxacum*) and *T. nordstedtii* (sect. *Spectabilia*) are concerned the relation is confirmed by OOSTERVELD (1983). The data in *table 9* illustrate that *T. lancidens* (sect. *Hamata*) belongs to the intermediate group, as originally is suggested by OOSTERVELD (1983)

A number of microspecies show a clear relation between the dry matter production and the productivity of the environment. *T. sellandii* and *T. ancistrolobum* (sect. *Taraxacum*). both found in heavily fertilized and grazed pastures, have a high production of biomass, form relatively few but large leaves and have high $\overline{LAR}$ and $\overline{LWR}$ values. These peculiarities can be considered to be adaptive in those habitats. By a fast development by means of large leaves the plants are able to colonize open places in the turf.

T. hygrophilum and *T. nordstedtii* (sect. *Spectabilia*), which are found in moist and lightly fertilized and grazed pastures, on the other hand, have a relatively low production of biomass and bear relatively small leaves, being apparently an adaptation to this type of environment. *T. nordstedtii* in particular has a low $\overline{LAR}$ and $\overline{LWR}$. The microspecies in question form a relatively great amount of roots.

Table 9 clearly shows that different taxa of sect. *Taraxacum* sometimes exhibit clear resemblances in their growth characteristics, conceivably as a consequence of the close evolutionary interrelationships within the still young section on the one hand but sometimes there are appreciable differences in growth form, showing ecological adaptions to different environments. It is noteworthy in this connection that morphologically clearly distinguishable microspecies may exhibit a considerable ecophysiological resemblance (*e.g., T. sellandii* and *T. ancistrolobum*).

Table 9. Ecology and growth characters of the microspecies studied.
The significance of an ecological factor or the importance of a feature are indicated as follows: + + +: highly meaningful; + +: moderately meaningful; +: of little significance; −: unrecorded or absent; mod: moderate.

Microspecies	Sect.	Ploidy	Ecology				Growth characters					
			Moisture	Grazing	Fertilizing	Prod. Env.	Mean dry matter prod.	$\bar{R}$	Mean leaf surface	Mean number of leaves	$\overline{LAR}$	$\overline{LWR}$
T. sellandii	T	3x	mod.	+++	+++	+++	+++	++	+++	++	+++	+++
T. PP23	T	2x	mod.	−	+++	+++	+++	++	++	+	++	++
T. ancistrolobum	T	3x	mod.	+++	+++	+++	+++	++	+++	++	+++	+++
T. ekmanii	T	3x	mod.	+++	+++	+++	++	+++	++	++	++	+++
T. limburgense	T	2x	mod.	++	++	++	++	++	++	+	+++	+++
T. HL33	T	2x	mod.	++	++	++	++	+++	++	+++	+++	+++
T. adamii	T	3x	moist	+	+	+	++	++	++	++	++	+
T. raunkiaeri	T	3x	mod.	++	++	++	+++	+++	++	+++	+++	+++
T. lancidens	H	3x	mod.	++	++	++	+++	+++	++	++	++	++
T. taeniatum	E	3x	dry	−	−	++	+++	++	+	++	++	+++
T. hollandicum	P	3x	moist	+	+	++	+	+	++	+++	++	+++
T. hygrophilum	S	3x	moist	+	+	+	+	+	++	++	++	++
T. nordstedtii	S	6x	moist	+	+	+	+	+	+	+	+	+

No clear relation could be established between the differences in morphological features (*e.g.* in the leaf morphology) and in the ecophysiological characteristics. A marked difference in the leaf characters does not consistently coincide with an appreciable difference in the ecophysiology, nor small differences in the leaf morphology with small differences in ecophysiology, respectively.

Within sect. *Taraxacum* clear differences were noted. Along with the highly productive microspecies *T. sellandii* and *T. ancistrolobum* there is a group (to which *T. ekmanii, T. raunkiaeri* and *T. adamii* do belong) with a clearly lower biomass production. According to STERK et al. (1983), *T. ekmanii* appeared to grow mostly sympatrically with *T. sellandii* and *T. ancistrolobum* in heavily fertilized pastures, but HAGENDIJK et al. (1982) mention that *T. ekmanii* also often occurs in hayfields and along dijkes and roads, on mostly poorer soils. Accordingly, *T. ekmanii* most probably has a rather broad ecological amplitude. The sites, where this microspecies was studied by STERK et al. (1983) represent rather extreme habitats. There are, accordingly, arguments not precluding that in *T. ekmanii* a lower biomass production is adaptively related to a less productive environment.

As regards *T. raunkiaeri* and *T. adamii* their lower biomass production can be considered as adaptations to less heavily fertile environments than those preferred by *T. sellandii*. *T. raunkiaeri* prefers fairly fertile, sandy soils; its relatively large mean number of leaves per plant, which feature it shares with *T. hollandicum* (sect. *Palustria*), is characteristic. *T. adamii* is often found sympatrically with *T. nordstedtii* in moist, lightly fertilized pastures (HAGENDIJK et al. 1982, STERK et al. 1983). The taxonomic position of *T. adamii* is somewhat obscure. According to some authors this microspecies does not belong to sect. *Taraxacum* but to sect. *Spectabilia* (RICHARDS, 1972).

The sect. *Hamata* form a group of species with a large ecological amplitude, preferring more or less moist and not heavily fertilized nor intensively grazed pastures (STERK et al. 1983, OOSTERVELD 1983). Thus in *T. lancidens* the moderate production of biomass correlates with a moderately productive environment.

T. hollandicum (sect. *Palustria*) is a species of a fairly fertile environment found in lightly fertilized pastures, but thriving in habitats on river clay soils along the great rivers rich in minerals and in nitrogen (HAGENDIJK et al. 1975).

T. taeniatum (sect. *Erythrosperma*) shows a moderate production of biomass and prefers a dry, sandy and nutrient-poor environment in the coastal area. On the other hand, *T. nordstedtii* exhibits a clear correlation between the low productivity of its natural habitat and its low dry-matter production. It may be concluded that *T. taeniatum* has a greater phenotypical and physiological plasticity in respect of the nutrient level of the soil than does *T. nordstedtii*. Presumably owing to the lack of natural selection this plasticity has not become much narrowed down and properly adapted because this microspecies is hardly ever encountered in nutrient-rich habitats.

4.2. Growth characters and ecology of diploid sexual microspecies of sect. Taraxacum

T. limburgense, by being the only recognized diploid and sexual representative of sect. *Taraxacum* in The Netherlands (STERK, DEN NIJS & KREUNE 1982), takes up a special place. Its ecology is roughly known: it is found in stream valleys in the 'Krijt-District' and the 'Löss-District' in the SE of The Netherlands, where it seems to prefer lightly to moderately fertilized grasslands. In the more intensively managed, agricultural grasslands bordering these valleys it has not been recorded (ELZINGA & VAN DER KAMP, 1984). *T. limburgense* is found at the extreme boundary of the distributional area of the sexual diploids in Western Europe. Possibly the restricted occurrence of this microspecies in stream valleys is caused by the local microclimate, favouring the fertility of sexual plants (*i.e.,* the production of achenes and/or achene production), the seed set being dependent on suitable pollinaters and the fertility of the pollen. There are indications that in general the Dutch climate is not very favourable to the life-time and the rate of germination of *Taraxacum* pollen. *T. limburgense* is a moderately productive taxon. This also holds for THL33 from Switzerland, but not for TPP23 from southern Germany (*table 9*). This renders it plausible that within the sexual sect. *Taraxacum* in Western Europe the range of variation in biomass production in sexual diploids is not narrower than in agamospermous triploids. In Central Europe most probably also diploids may be adapted to strongly fertilized and nutrient-rich, agricultural environments.

4.3. Conclusions

In general, microspecies of the sections *Taraxacum* and *Hamata,* originating from productive environments have a high biomass production and large leaf areas. They form relatively few but large leaves. Microspecies of the sections *Spectabilia* and *Palustria* from low-productive environments (moist and lightly fertilized and grazed pastures) have a low biomass production and small leaf areas. They bear relatively small leaves. These findings may be considered to be adaptations to the environment. There are genetically determined differences between microspecies in their mean dry matter production, in the mean number of leaves per plant, in the mean leaf area per plant and the mean surface area per leaf, in the root/shoot ratios, in the relative growth rate values and in the optimal growth temperature. This means, in practice, that the results obtained are not directly comparable with data from the pertaining literature, as far as they are related to *"T. officinale",* as is nearly always the case, (*e.g.,* in GRIME & HUNT, 1975) or to *Taraxacum* spec. (VAN ANDEL et al. 1984).

From an evolutionary point of view the diversity in growth parameters is of considerable importance, because it is speculated that in Europe the genus *Taraxacum* is in an active phase of micro evolution. This especially holds for sect. *Taraxacum* in which there is an adaptation to recently established and very nutrient-rich, unstable grassland biotopes. These adaptations take place at the diploid (sexual) level in Central and southern Europe, and mainly at the triploid, agamospermous level in both Central and northern Europe. In other respects

the separation between the ploidy levels is not very sharp. Most probably there are diploid-polyploid cycli constituting and adaptive system (JENNISKENS 1984, DEN NIJS & STERK 1984). The sections *Spectabilia, Palustria* and *Erythrosperma* are upon the whole of a more limited occurrence in older and not heavily fertilized and grazed biotopes, whereas the sect. *Hamata* takes up a more or less intermediate position and prefers lightly to moderately fertilized and relatively moist, not too well-drained grassland biotopes. As regards the questions posed in the introduction, this conclusion means that the occurrence of microspecies (or groups of microspecies) of *Taraxacum* in a given landscape is chiefly determined by their genetically defined, ecophysiological characteristics.

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