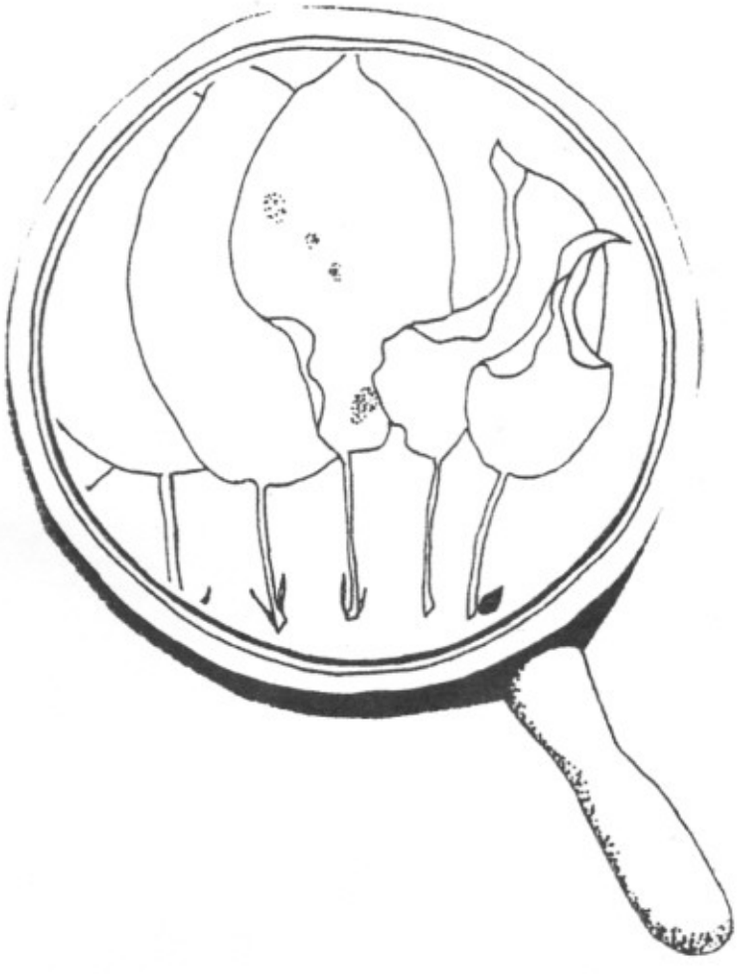
ORGANIC FRUIT GROWING

Leaf series as an image of shoot growth



Method, examples and interpretation: Revised edition, 2000

Joke Bloksma en
PieterJans Jansonius

LOUIS BOLK INSTITUUT
natuurwetenschappelijk onderzoek

About the Louis Bolk Institute

The Louis Bolk Institute is an independent research institute in Driebergen, the Netherlands. Since its formation in 1976 it has encouraged research methods which focus on not only quantitative but also qualitative aspects. The aim of the Louis Bolk Institute is to contribute to the scientific and social needs for innovative research.
There is more and more collaboration in research projects where researchers of the institute work together with scientists from other institutes or universities on human health, organic agriculture and whole-food nutrition.

The agriculture department of the Louis Bolk Institute was established in 1987. The scientists work to develop and support organic and bio-dynamic agriculture. To do so, they research locally on farms, participate with farmers to formulate questions to be tested on farms and perform fundamental research in experimental gardens. They exchange their knowledge and insights with the farmers and who are involved.

You can order a general Annual Report about the Louis Bolk Institute, the publications list or an annual report only about organic fruit growing research section.

For more information:

Louis Bolk Institute,
Hoofdstraat 24, NL 3972 LA Driebergen,
The Netherlands
Phone: +31-343-517814
Fax: +31-343-515611
E-mail: info@louisbolk.nl or www.louisbolk.nl

EDITOR
2000, Louis Bolk Insitute, Driebergen.
Please, use reference if cited.

Publication LF58.
This is the English version of the Dutch publication LF57 and part of the series of publications in ORGANIC FRUIT GROWING RESEARCH of the Louis Bolk Institute.
You can order publications by phone, fax or e-mail.

Table of contents

Summary

The sequential leaves of the shoot show a 'biography' of the growing season. The shape of the leaves shows the conditions under which the leaves are formed. To save this picture, the leaves are picked from the shoot, dried and pasted next to each other. If necessary, they are also drawn. The distance between the petioles is equivalent to the original distance of the leaves along the shoot. This is referred to as a 'leaf series'.

The advantages of working with leaf series include:

- The leaf series provides a picture of the development in time and not only the final result. For example, it is possible to recognise periods with luxuriant growing conditions or poor growing conditions.
- The leaf series comprises various characteristics such as shoot length, leaf size, regularity, etc. It is a 'total picture'.
- The leaf series contributes to better communication between researcher and fruit grower. Fruit growers know and evaluate their trees as a 'picture' and not as a 'number'.
- This concerns a representative shoot and not an observation which you need to repeat ten times and calculate the average and standard deviation.

This method was developed to help answer the questions of fruit growers and researchers. Fruit cultivation researchers need to record vegetative development during the course of the growing season. The quality of the shoots with the leaves determines the 'production capacity' of the tree and the quality of the fruit and the buds for the next year. Fruit growers need extra characteristics to be able to evaluate their trees themselves and to see in the field whether they have taken the proper cultivation measures.

The Louis Bolk Institute introduced the concept of the 'leaf series method' in 1992. Since then the Institute has continued to develop the method during a number of research projects. This is a revised publication about the method with recent examples.

1 General aspects of the method

1.1 Introduction

In fruit cultivation research, it is frequently difficult to properly describe the vegetative growth of a tree. One is usually limited to the final result: the total length of the new shoots or to a kind of 'evaluation grade' for the vitality and leaf color. Additional insight into the development during the growing season may also be desirable. It makes a great deal of difference whether a shoot grows steadily, or with starts and stops, to its final length.
In addition, some fruit growers need to evaluate their trees based on what they see in the field. This allows them to be less dependent on the results of laboratory tests. In response to such requirements from research and practice, the Louis Bolk Institute is attempting to develop the 'leaf series' method, where successive leaves on a shoot are viewed as a sort of biography of the growing season. The shape of the leaves shows the conditions under which the leaves were formed.

In order to improve the observation of the shoot, to make comparisons with other situations and to store the observations, the leaves are picked, dried and pasted next to each other. During this procedure, the distance between the petioles (internodes) is equivalent to the original leaf-to-leaf distance.

This method was introduced in 1992 by the LBI as a possibility and was published in 1996 at the request of other researchers who also wanted to experiment with this method (Bibliography 1.2). At that time, many questions were still unanswered:

1. How do you choose the shoot as consciously and objectively as possible?
2. Which standard do you choose for comparison?
3. Is it possible to make a precise time indication when each leaf is formed? In order to do this, must you know how long the internodes continue to stretch after the young leaf splits off?
4. For which objectives can a leaf series be more pertinent, simpler or cheaper than the usual analyses? And more importantly, can you see something about the nitrogen supply from the leaf series?
5. Is this method also useful for short shoots?
6. Is there a relationship between 'regularity' in the leaf series and fruit quality? If so, can regularity be used to predict good quality?

In the present version (2000), questions 1-5 are answered or partially answered. Question 6 remains open for future research. In addition, we have used this method in a number of studies and added details to the method description. Of course, we remain open for further improvements. In this booklet, the method itself is described in Chapter 2. The background and foundation of the method are described in Chapter 3. For the time being the emphasis lies on application to apple cultivation. Examples of research applications of the leaf series method are presented in Chapter 4.

We do not assume that fruit growers will use this laborious method of picking, drying and pasting. Growers usually observe the intact shoot on the tree. The method described here for interpreting a drawn leaf series is, however, equivalent to interpreting the shoot on the tree. Picking and pasting is only necessary if the image of the shoot must be saved.

1.2 Aspects of working with leaf series

1. The leaf series provides a picture of the development of the shoot in time. This provides supplemental information to measurements of the total shoot length in the winter following the growing season. The latter method provides only a final result.
2. The leaf series summarises various parameters: shoot lengths, leaf size, regularity, etc., and can be used if one wants to have a 'total picture'.

3. The leaf series contributes to better communication between researcher and fruit grower. The visual material frequently links up better with the image that fruit growers have of the growth of their trees than do figures about leaf colour, average shoot length, etc. Fruit growers know and evaluate their trees as an 'image' and not as a 'number'.
4. A leaf series is not a type of observation for which you need to make ten repetitions spread across a plot and then calculate an average with a standard deviation. It involves searching for a single representative shoot. If there is a great deal of variation, two or three leaf series may be necessary to produce a representative picture. A representative shoot can be chosen in various ways (see § 1.3).
5. Viewing a leaf series sometimes opens your eyes to characteristics which you did not previously pay attention to in the field. Consequently, new hypotheses can be generated for further research; see for example § 4.1.

1.3 Types of leaf series

Depending on the question being studied, one can choose a specific type of leaf series. The following types can be distinguished:

1. **Leaf series as a picture.** This series is used to illustrate other observations such as average shoot length, leaf size and degree of infestation. The leaf series does not add any new information. This type of leaf series is useful for summarising various types of information in a visual image. When picking leaves from this single shoot, the relevant average values have already been calculated, and one is looking specifically for a shoot which illustrates the average. This is the type of application with which we have worked most frequently in the past.

2. **Leaf series as an image**. This series is used as a reflection of what the observer experiences as characteristic growth of the relevant plot or tree. The choice of shoot is personal and subjective. It may deviate from the average value or sometimes the averages are not even known. The choice is often somewhat exaggerated to emphasise a particular characteristic. The choice of shoot takes place following extensive observation with a well-practised 'fruit grower's eye'. The observer walks between the trees to form an inner image of all aspects of growth. To summarise this impression, he or she chooses a tentative shoot, which is again evaluated while continuing to walk through the orchard. If desired, various observers can compare their tentative characteristic shoots. By explaining their choices to each other, the eyes of the various observers are opened to more and more aspects. As the observational capacity of the observers increases, the difference between the definitively chosen shoots decreases. Consequently, this method is intersubjective in the sense that it is personally coloured but transferable. In consulting or extension research, it is useful for the grower and the researcher to go through this process together, allowing them to 'learn to look' from each other.

3. **Leaf series as a developmental sequence**. This series is used if one must know very precisely when each leaf develops in time. For example, if it is important to know how vegetative growth reacts to weather conditions, or if one needs to pinpoint the infection period using observations of leaves with scab. As the long shoots begin to grow, a number of beginning shoots are marked and provided with a shoot ruler (see Chapter 2). After this, the length is measured every one to two weeks and/or the number of developed leaves are counted. If the shoot ends at a terminal bud, the shoot can be harvested, the leaf series pasted and the date of development recorded. Because the shoot is chosen at the very beginning of the growing season, one doesn't know if it is going to be a representative shoot. Marking a number (five to ten) of shoots and then choosing the most average or most representative one at a later date can partially solve this problem.

Summary of the three types of leaf series

	Objective	Choice
1 **Leaf series as a picture**	provide visual image to illustrate known data about shoot growth	following the growing season when average values are known, a shoot is chosen which is most representative of the average
2 **Leaf series as an image**	to express the characteristic vegetative growth of a specific tree or plot	following the growing season, after careful observation, the most characteristic shoot is chosen subjectively or intersubjectively (may be somewhat exaggerated)
3 **Leaf series as a developmental sequence**	provide an overview of the development of the leaf sequence in time in which the weather conditions and/or moments of infection are recognisable	before the growing season, several shoots are marked, than measured every two weeks, allowing the dates of the formation of every leaf to be known

1.4 Time of harvest

Shoots can theoretically be harvested during the entire period beginning as soon as they are growing vigorously (around mid-June) and ending just before leaf drop. To obtain a picture of the entire growing season, one must wait until the growth has stopped (somewhere between the end of June and the beginning of September). Possible summer pruning, leaf damage and early leaf drop are reasons to not delay the harvesting any longer than is necessary. Short shoots can be harvested sooner (see § 1.8).

1.5 Standardisation

The growth of a shoot depends on many conditions; for example, the location within the tree, the shoot orientation, whether or not the shoot emerges from a spur, and the number of fruits at the base of the shoot. To indicate the magnitude of these differences, illustrative series are shown in § 3.2, 3.3 and 3.4.

If trees or plots must be compared with each other, standardisation for specific situations is essential. This applies to shoots being used for all three of the objectives. For the time being, the following 'standard shoot' has been chosen:

- At chest height (with non-vigorous root stocks)
- Mixed shoot thinned to a single fruit (unless research requires something different)
- A shoot orientation of 45 degrees to the vertical. Not a side-shoot from the trunk, no terminal shoot or terminal fruit (unless the research requires something different)

With the apple cultivars Elstar, Jonagold and Boskoop, this standardisation works satisfactorily during a single year and within a single plot. It is more difficult to standardise in such a way that series from various growers and various years can be compared with each other. For example, a shoot growing at 45 degrees (which is marked in May) has bent down during the next few months and in August can no longer be classified as a 45-degree shoot. We have therefore moved away from the idea that a true standard can be prescribed. We now select only a standard within a single study which is relevant for the situation. For example, 'vertical spur shoots approximately 10 cm long' is also a useful standard (see § 4.5). With trees where the leaf rosettes hardly grow into shoots (for example the apple cultivar Alkmene or a tree with a heavy load of fruit), no representative mixed shoot can be harvested. For short shoots, presentation of the leaf series in a circle can be clearer than in a straight line (see figure § 3.7). The quality of short shoots is important primarily for the period between flowering and leaf drop. It is difficult to find a 45-degree shoot in many pear trees. Our experience with pears is still limited; a separate standardisation method must be de-

veloped for this. Plums and cherries do not have mixed shoots; one must work with long shoots in these species.

1.6 Viewing the leaf series

When viewing a leaf series, the following characteristics are important:

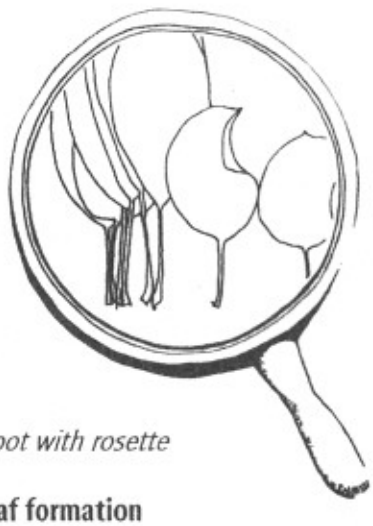
- Shoot length
- Number of leaves
- Whether new leaves are still forming or whether shoot ends with a terminal bud
- Distance between sequential leaves (= internodes)
- Length of petiole
- Size of stipules and degree of fasciation of the stipules
- Leaf shape: leaf size, ratio of leaf length to leaf width, leaf bumpiness (recognisable after drying as 'pleating')
- Leaf colour (is lost after drying)
- Fine details such veining and leaf serration (lost when drawing only the leaf circumference)
- Infestations such as scab, insect damage, curling caused by aphids
- Regularity in above characteristics, primarily during the transition from rosette to shoot
- Leaf area (scan the leaf circumference and calculate the surface area by using computer)

1.7 Interpreting leaf series

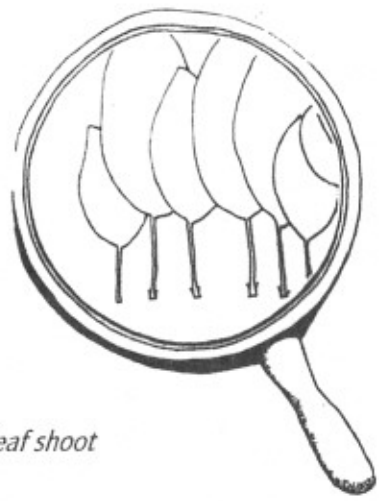
Below are examples of the type of information that can be derived from a leaf series. To support these interpretations, some of these characteristics are compared with other observations in Chapters 3 and 4.

Vegetative shoot or mixed shoot

A mixed shoot can be recognised by the rosette formation; this can be seen in the leaf series where there are many leaves close together at the base of the shoot. A vegetative shoot begins with leaves that are further apart. A mixed shoot with no fruit set shows a picture which is between the above two examples.



mixed shoot with rosette



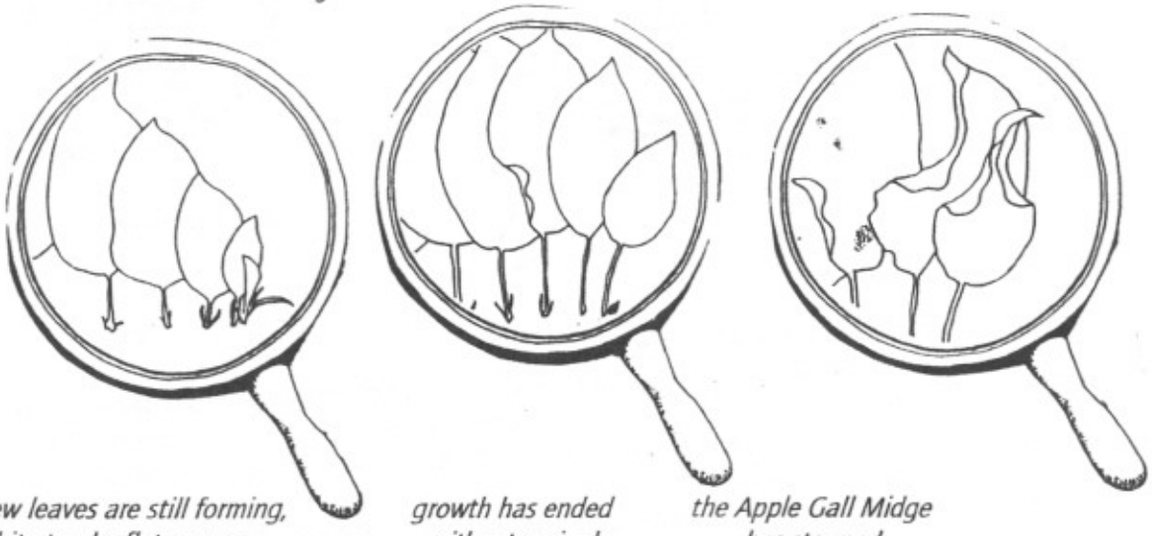
leaf shoot

Date of new leaf formation

To show a reliable relationship between the location of the leaf along the shoot and the date of leaf formation on the shoot ruler, is it important that the internodes do not continue to elongate? To answer this question, a weekly series was made and illustrated in § 3.1. In this example, the internodes continue to elongate only during the week when the new leaf is formed. Thereafter the leaves no longer shift along the

shoot. It is therefore sufficient to note the length of the shoot and the date throughout the season. Following completion of the observation, it is clear which leaf was formed in which week.

Growth has finished or is continuing



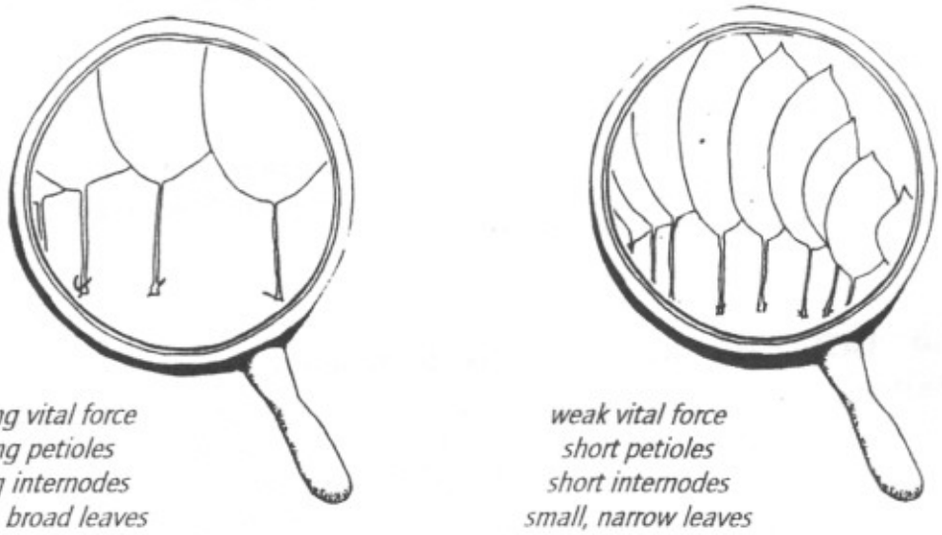
new leaves are still forming, white top-leaflets mean that the growth will continue for another six weeks

growth has ended with a terminal bud

the Apple Gall Midge has stopped shoot growth

Measurement of vitality

Strongly growing trees have long shoots; petioles are far apart and there are many leaves. The leaves are large and shoot growth stops only late in the year with a terminal bud.

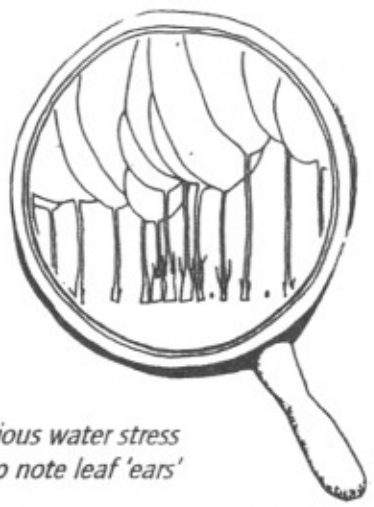


strong vital force
long petioles
long internodes
large, broad leaves

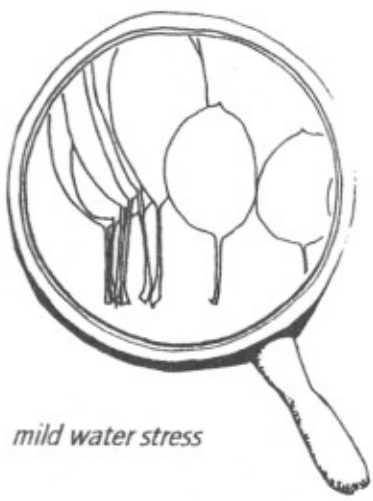
weak vital force
short petioles
short internodes
small, narrow leaves

Water stress

Periods with extreme water stress are shown by small leaves and short internodes, followed by regrowth with strongly fasciated, large stipules (see § 4.3).
If the water stress is less extreme, as occurred with several orchards in 1996, the dry period can be recognised by small leaves without fasciated stipules (see, for example, § 4.2: third series).



serious water stress
also note leaf 'ears'



mild water stress

Nitrogen supply during the growing season

We investigated whether it would be possible to precisely read the nitrogen status of the shoot throughout the season from the leaf series. High nitrogen levels can be recognised by the large and dark green leaves that are produced. However, a physical change in the leaf is seen only at very low nitrogen levels. The leaves become smaller, yellow-green and more sharply serrated with red tips. Moreover, small leaves are caused not only by low nitrogen levels, but also by all sorts of growth inhibition; heavy fruit bearing (§ 3.5), water stress (§ 4.3), virus (§ 4.4), etc. Nitrogen analysis of the leaf tissue is still necessary to indicate smaller changes in the average nitrogen supply. For a number of leaf series, the nitrogen levels of plot samples are reported.

Description of the growing season

In 1996, there was a good spring. Large, round leaves were present in May. In June and July, it was very dry, recognisable by the small leaves. It rained regularly in August, the leaves then became larger (for example, see § 4.2: third series).

Resistance against infestations

When evaluating the spraying scheme, one can determine during which period the scab control was insufficient by noting the location of leaves with scab. In this example, the shoots with luxuriant growth had the most scab infestation (see § 4.2 and § 4.4).

1.8 First experiences with short-shoot series

If a short-shoot series is presented in a straight line, a great deal of information is lost if all the leaves are pasted more or less on top of each other. We therefore selected a half-circle presentation in sequence of emergence to use with short shoots. Examples of short-shoot series are shown in § 3.7 and § 4.8. Short-shoot series are especially important when making evaluations in May, when hardly any long shoots have been formed. At this point, of course, no complete biography of the growing season is present. We must also emphasise that the actual orientation in space surrounding the terminal bud is different than the sequence of formation as shown in the series. Examples of spatial orientation are shown in sketches in § 3.7.

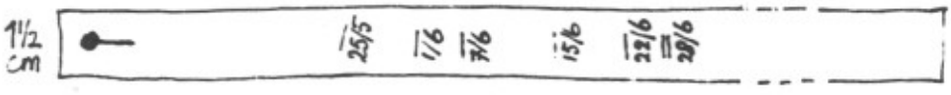
2 Instructions for making a leaf series

When making a leaf series, five steps can be distinguished. Depending on the objective of the leaf series, more or fewer steps may be necessary:

1. Marking the shoot on the tree

Marking and tracking the shoot on the tree is only necessary with a 'developmental sequence', where it is important to determine which leaf develops in which week. In May, mark three shoots in order to choose the most representative one at a later date. Shoots are marked by attaching a 'shoot ruler' to the shoot. The shoot ruler remains attached during the entire growing season. The shoot length is marked by putting a line and a date parallel with the growing tip of the shoot using a fine tip permanent marking pen.

Required materials: shoot rulers, permanent marking pen (1mm).



Self-made shoot ruler of brightly coloured nylon which is torn into strips approximately 1.5 cm wide. The length is modified according to the expected maximum shoot length. On one side, a hole is made (using a punch) and a lengthways split 1.5 cm long is cut (using scissors), similar to sleeve labels.

2. Selecting and harvesting

This step is important when 'series as image' is being made. Selecting the shoot in the orchard takes about 10-30 minutes per shoot, depending on experience and the number of people who have to agree about the choice. The selection process is described in 'types of leaf series' in § 1.3. If selection is concerned only with achieving mutual agreement about 'what is characteristic', Step 2 is sufficient. If the shoot must be 'stored', extra steps must be taken: the selected shoot is marked and stored in a plastic bag in the refrigerator (maximum two days) until time is available for drying the leaves.

Required materials: marking tape, marking pen, plastic bags.

3. Drying

The shoot is placed alongside a ruler or tape measure and every leaf is picked off individually. Each leaf is given its own page in, for example, an old telephone book, where the original distance to the shoot base is noted. Missing leaves along the shoot are given an empty page with a statement of the location of the empty axillary bud. This process takes about three minutes per shoot. The leaves can be stored for several days to several years in the book; they are pressed together by tying the book with rubber bands. When attaching the leaves during the next step, it is useful to have leaves that are not too dry and are still flexible.

Required materials: telephone books, large rubber bands, pen.

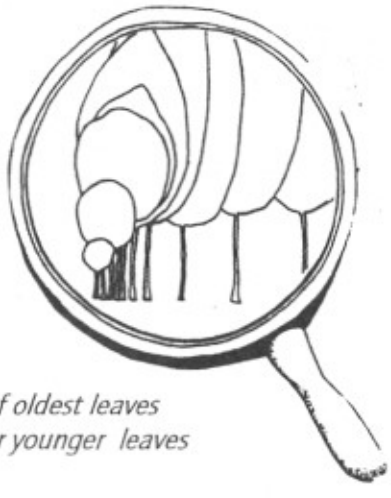
4. Attaching leaves

Sheets of white filter paper are very suitable for attaching the leaves because they are quite large and they absorb the remaining moisture quite well. The ruler is placed along the lower side of the sheet with the zero-point positioned 3 cm from the left side and 1.5 cm from the bottom. The leaves are removed one-by-

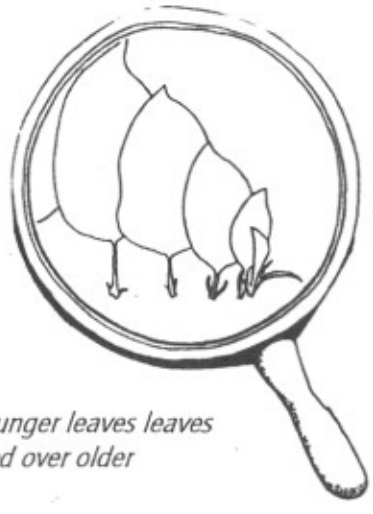
one from the telephone book. The end of the petiole is placed along the ruler at the original distance from the shoot base. The dried or half-dried leaves are attached so that the petiole, main vein and leaf tip are in a vertical, straight line as much as possible. The leaves are held in position with 'invisible' tape. This may require some adjustment because the leaves sometimes take on odd shapes after drying, especially bumpy leaves. To the left is the beginning of the shoot, with the initial leaves; the later leaves are attached over these leaves or partially covering them. As a result, the small, initial leaves frequently disappear under the larger, later leaves. If the first leaves are the most important ones in a study, then the sequence must be reversed! In this way, the youngest part of the shoot can be displayed most clearly. Show the terminal bud by drawing a thick dot in real size; indicate axillary buds of the missing leaves with small dots. The sheet of filter paper is then folded in half in such a way that the fragile leaf series is covered by the fold. In this way, the series can be stacked when they are stored. This entire process takes about six minutes per shoot. Leaf series which are used as demonstration examples can be laminated in plastic as soon as they are entirely dry. For very long shoots, two sheets of Ifilter paper must be attached together.

Once they are attached to a sheet of paper, the leaf series can be copied (at the lightest setting) on a copying machine while being reduced in size (but still retaining detail). For very fine details, such as the shape of the leaf edge serrations, enlarged copies of series are very useful.

Required materials: A3 sized sheets of white filter paper (obtainable from laboratory supply firms), long ruler, 'invisible' layout tape. Optional: A3 copy machine, transparent laminating plastic.



Example of oldest leaves attached over younger leaves



Example of younger leaves leaves attached over older

5. Tracing

If the leaf series must be published in reduced format, the visible parts of the leaf circumferences can be traced on tracing paper with a black drawing pen. The series can then be reduced on the copying machine as much as is necessary (from 50 to 20%) for them to fit into the publication. During this process, a great deal of detailed information is lost (serrated leaf edges, veining, scab lesions), but a traced series makes it easier to have a general overview (many series can be seen at a glance, strange colours that appear after drying are no longer distracting, broken leaf tops can be restored when tracing, etc.). When tracing, all aspects of the leaves which became distorted during drying can be restored: stipules can be drawn in their initial vertical position, bent petioles can be drawn straight, unimportant or uninteresting leaf damage can be restored. Each leaf is traced individually, there is no 'fusing', where the leaves are attached on top of each other. Place a centimetre scale with a code next to the drawing so that the original scale remains known after the series is copied and reduced in size.

Tracing requires about ten minutes for each shoot, or around 30 minutes per shoot if all serrations on the leaf edges are traced.

Required materials: Drawing pen (0.5 mm nib with Indian ink), tracing paper (approx. 85 grams per square metre), centimetre markings, copying machine.

Codes used by LBI

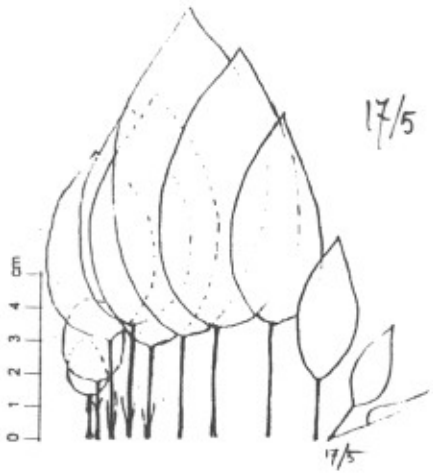
Attachment date: year, date, month.	Example: '961508-PEN-Ea': 965108 (15 August 1996)
First two capital letters of the last name of the grower.	PE (grower Peters)
First capital letter of name/number of plot	N (plot Negenvingerland)
First capital letter of the cultivar, ABC etc.	E (apple cultivar Elstar)
a,b,c etc. for special subdivision or variants.	a (Series a, there is also a Series b,c)

3 Relationship between leaf series and other characteristics

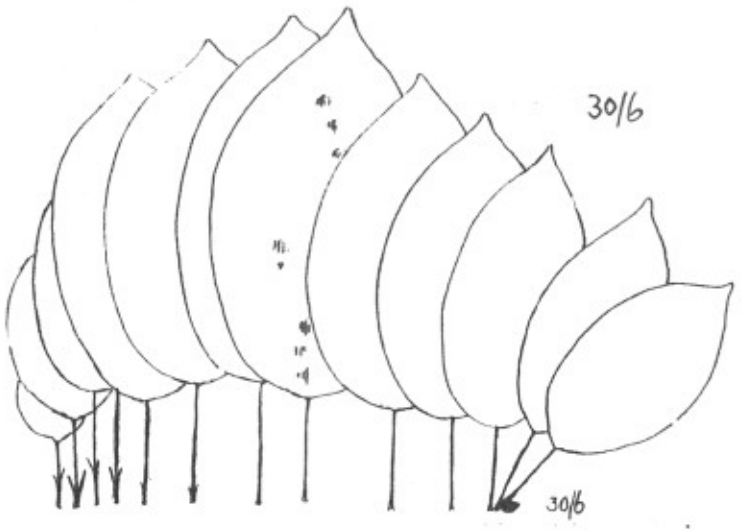
3.1 Growth of internodes in time

Developmental sequence of Elstar (see next page)
A number of these series were made to answer the question of how long the internodes continue to elongate following the formation of the leaf. This question was important for the use of shoot rulers. For these series, the leaves along the shoot were drawn every week without damaging the leaves. A single series is shown here as a representative example. Conclusions:

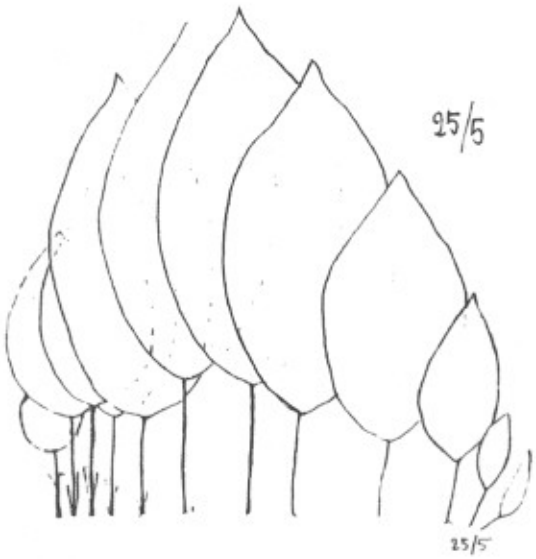
- Internodes elongate only in the week of the formation of the new leaf. Afterwards they elongate no further.
- The petiole quickly reaches its final length.
- The leaves are initially pointed, growing to their maximum length, then increasing in width for several weeks until the leaf becomes more rounded both at the tip and the foot.



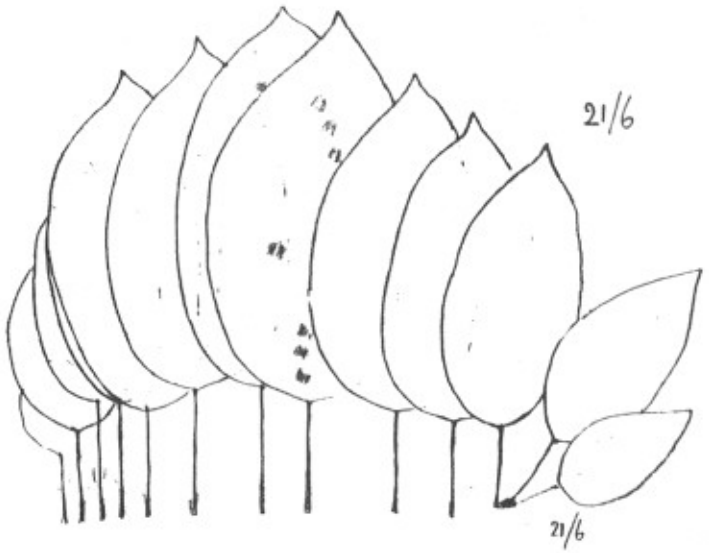
991705-BL-E: 17 May, shoot from mixed bud not pollinated, 45° horizontal;



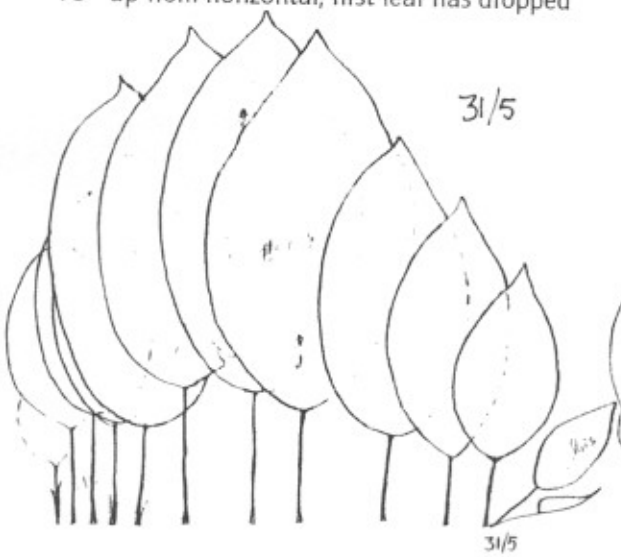
993006-BL-E: 30 June, the same shoot, 15° downwards; leaves are at final size



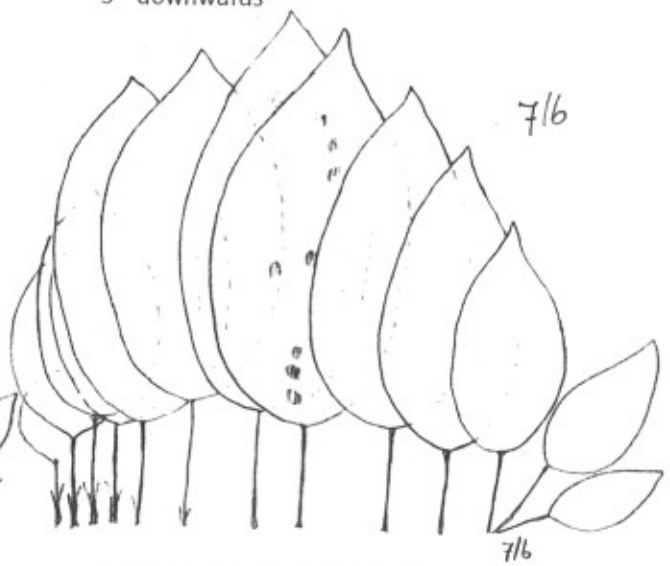
992505-BL-E: 25 May, the same shoot 15° up from horizontal; first leaf has dropped



992106-BL-E: 21 June, the same shoot, 5° downwards



993105-BL-E: 31 May, the same shoot, 5°up from horizontal;

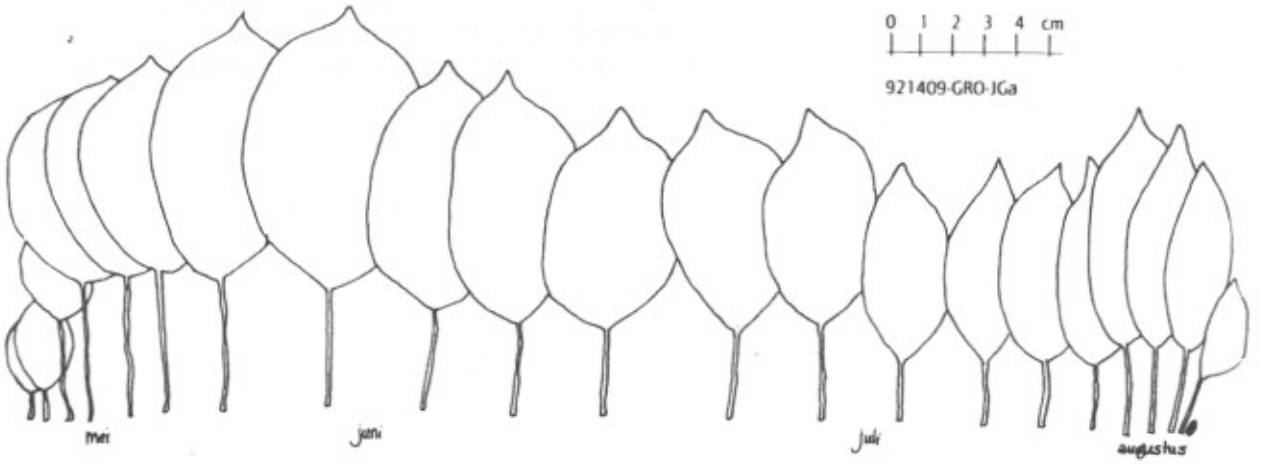


990706-BL-E: 7 June, the same shoot, horizontal

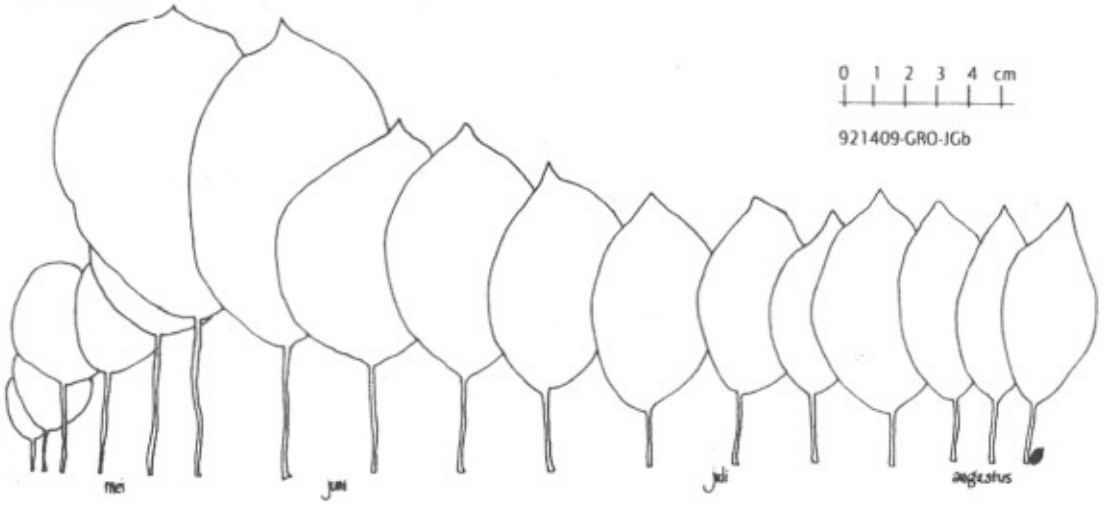
3.2 Shoot orientation

Leaf series as image of James Grieve

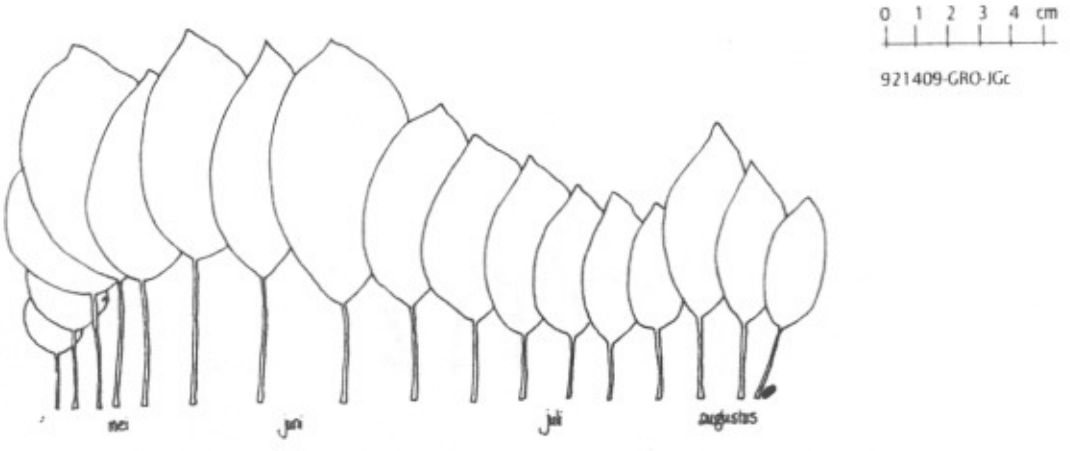
The orientation of a shoot largely determines its growth force. Each series clearly illustrates this well-known rule. It is therefore important to standardise the orientation. A shoot with a 45-degree orientation in May can drop, due to its weight, until it is nearly horizontal in August. See § 3.1 and remarks concerning standardisation.



921409-GRO-JGa: vertical, mixed shoot, now without fruit



921409-GRO-JGb: mixed shoot 45 degree, horizontal angle, now without fruit



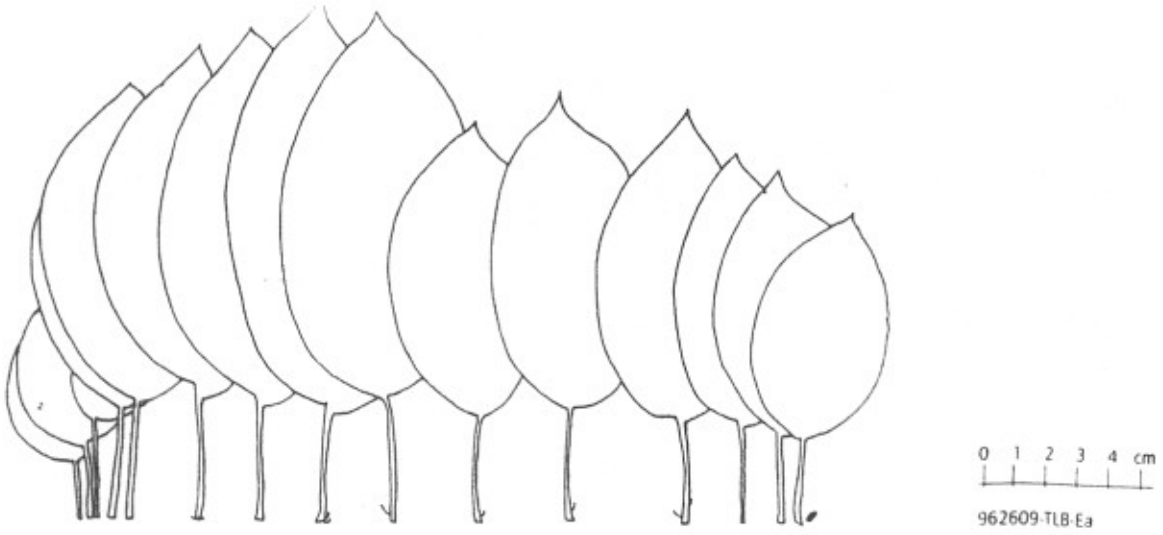
921409-GRO-JGc: horizontal, mixed shoot, now without fruit

3.3 Location in the tree

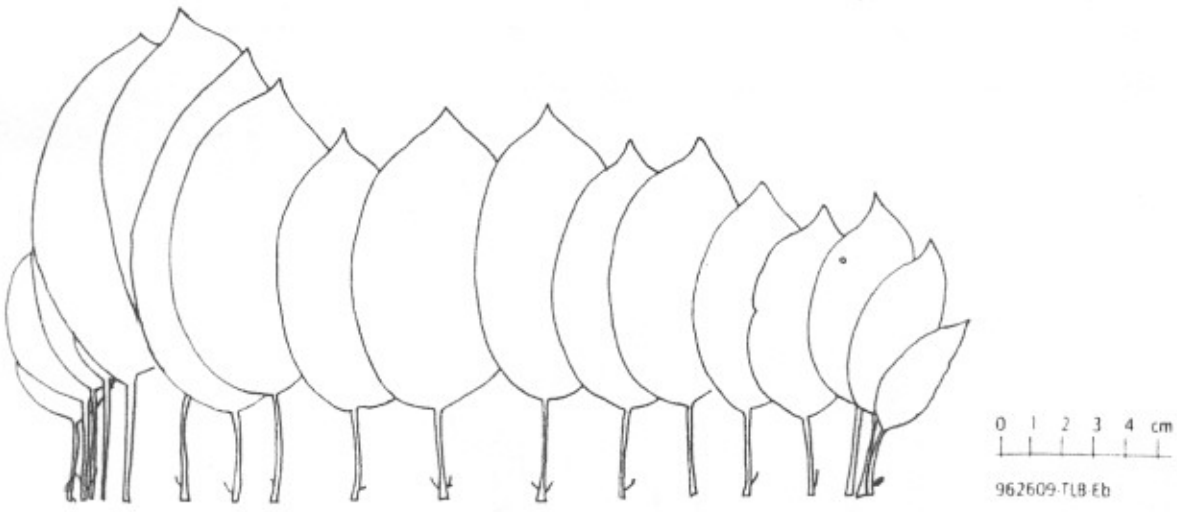
Leaf series as image of Elstar

All shoots began as mixed shoots, which can be recognised by the rosette formation. When the shoots were harvested, they had all lost their fruit. The large leaves of Shoot A were not characteristic for its location in the lower part of the tree; this is probably due to the loss of fruit relatively early in the season. However, the more pointed leaves from higher in the tree (c = most pointed; a = less pointed, b = in between) are characteristic of the location. The height in the tree therefore does not matter a great deal. Nevertheless, it is useful to standardise the location, for example at chest height (1.5 meters) with a weak root stock.

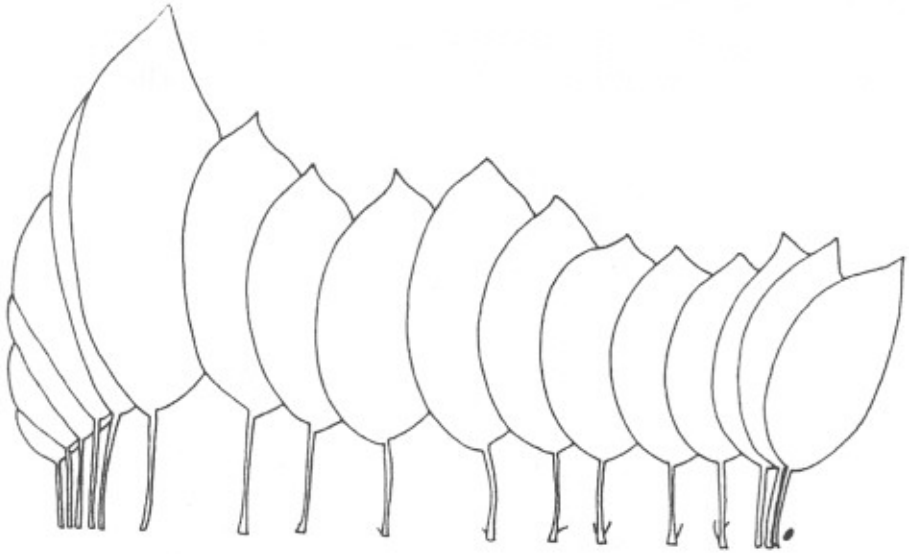
The shadow leaves had the same circumference but were thinner than sun leaves. The detail of leaf thickness is lost when leaves are traced. The location with respect to the sun is therefore tentatively included as part of the standardisation.

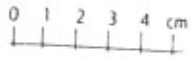


962609-TLB-Ea: Sun, low in the tree (Southeast, 80 cm)



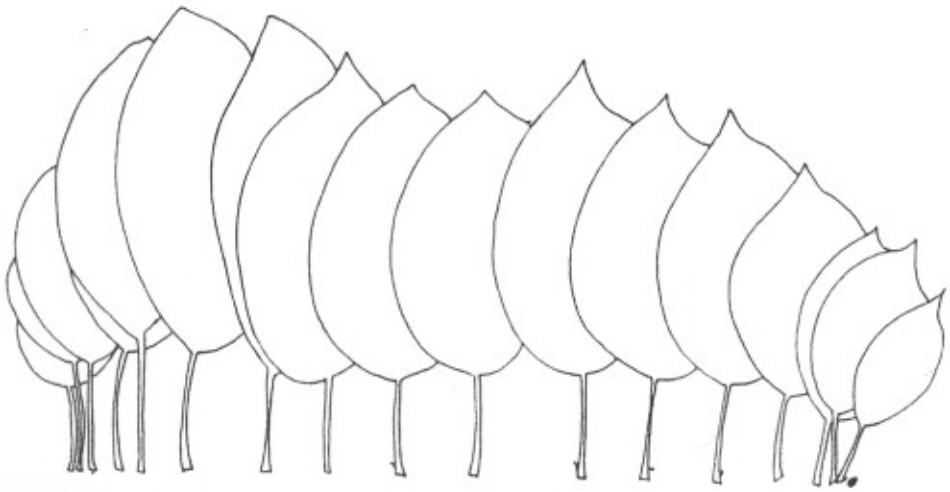
962609-TLB-Eb: Sun, middle in the tree (Southeast, 140 cm), N_{leaf}=2.1%(August)





962609-TLB-Ec

962609-TLB-Ec: Sun, high in the tree (Southeast, 200 cm)

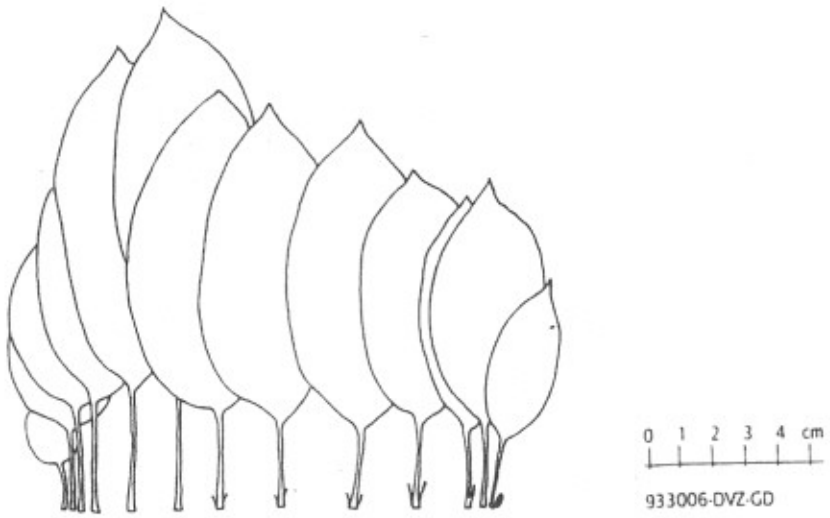


962609-TLB-Ed

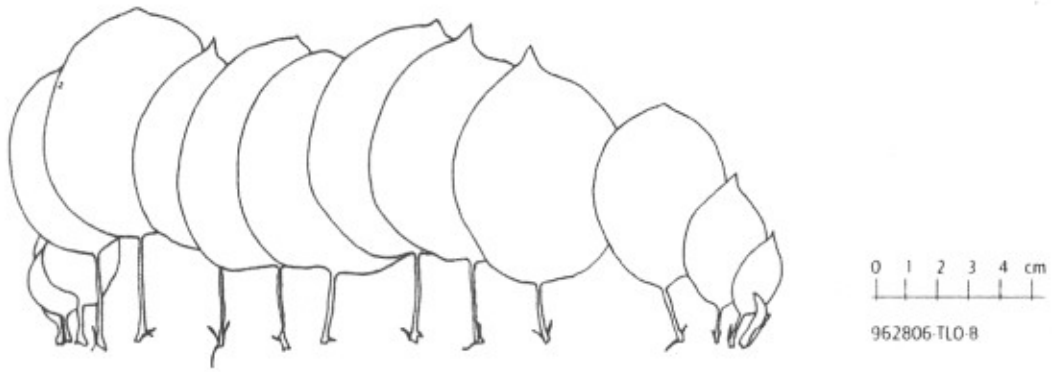
962609-TLB-Ed: Shade, middle in the tree (Northwest, 140 cm)

3.4 Differences between cultivars

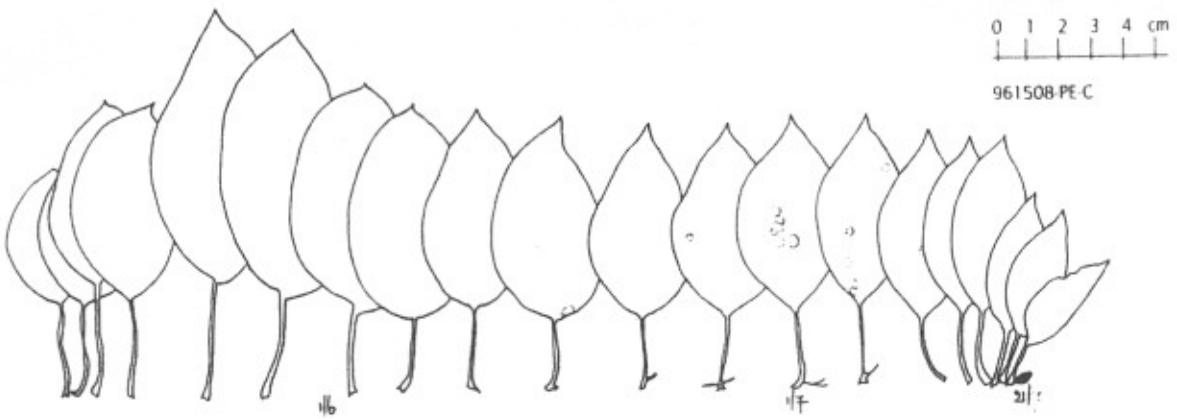
There is a difference between cultivars in the degree to which they express growing conditions. Apple cultivars such as Elstar, Jonagold, James Grieve and Boskoop are much more expressive than cultivars such as Cox's and Lombarts.



933006-DVZ-GD: Golden Delicious



962806-TLO-B: Boskoop



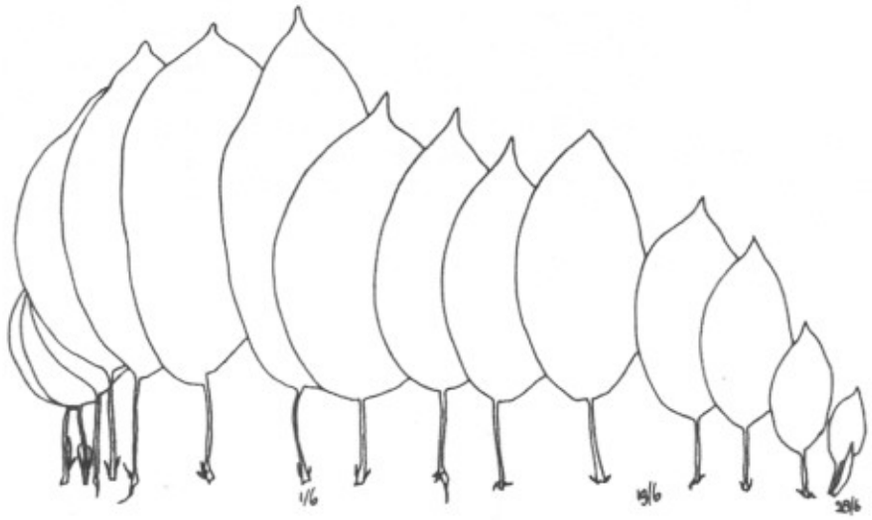
961508-PE-C: Cox's O.P.

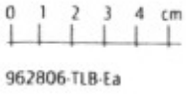
See § 3.2 for James Grieve; See § 3.3 for Elstar; See § 4.4 for Jonagold

3.5 Number of fruit

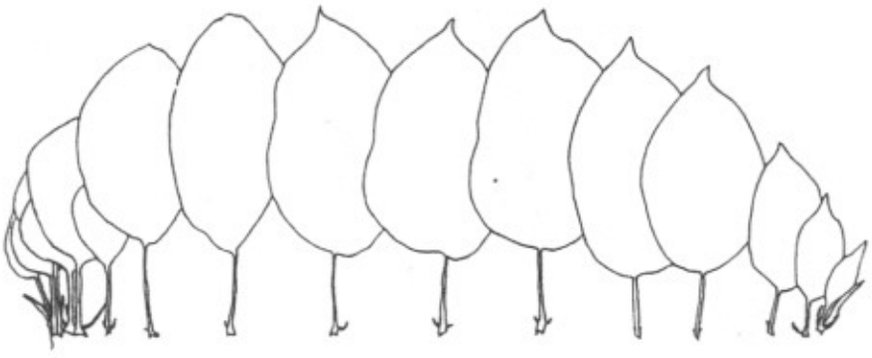
Characteristic series of Elstar, late June

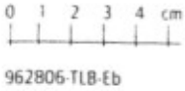
This series clearly illustrates the well-known relationship between an increase in the number of fruit and a decrease in vital force. The shoot is not only shorter, but the leaves also become significantly smaller, narrower and the internodes are closer together. The point in the season at which a shoot (or a part of a shoot) looses its fruit has a great influence on the vital growth.



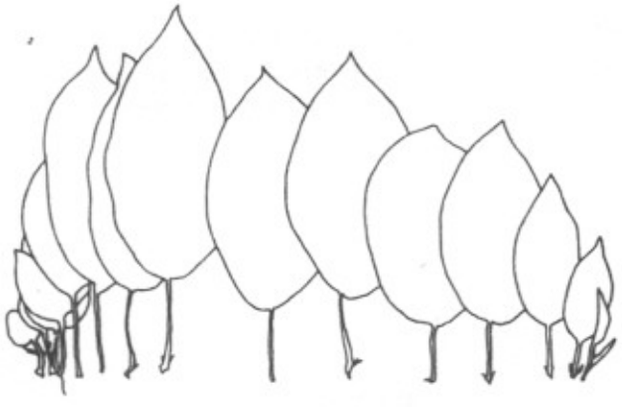


962806-TLB-Ea: shoot with 0 fruit

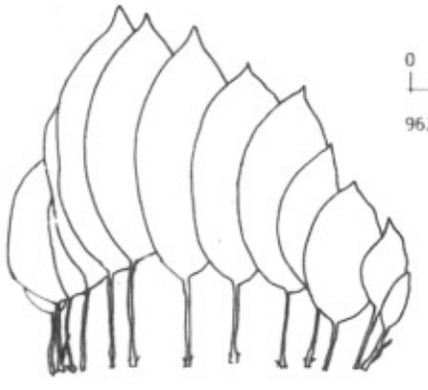


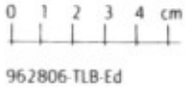


962806-TLB-Eb: shoot with 1 fruit



962806-TLB-Ec: shoot with 3 fruits





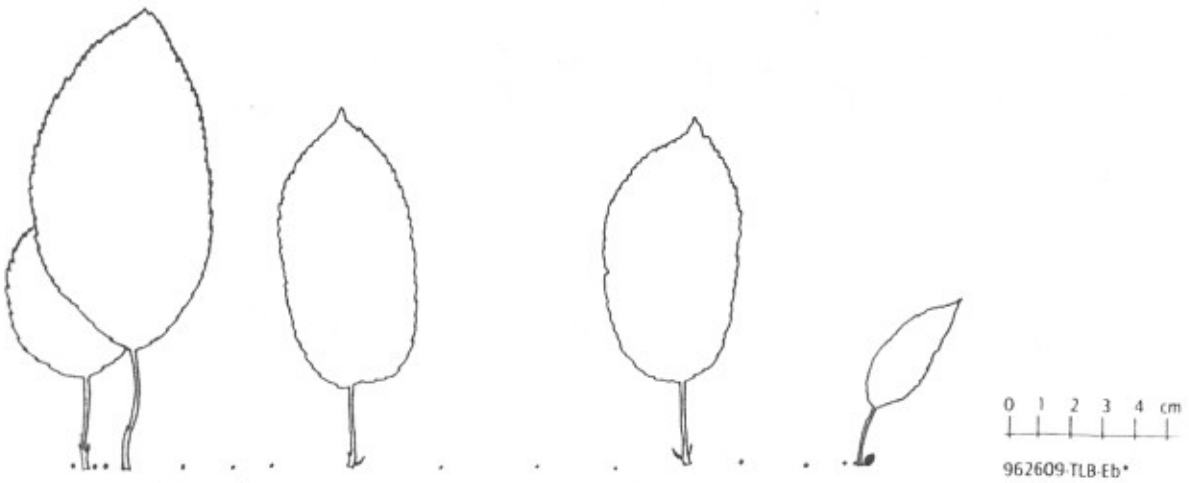
962806-TLB-Ed: shoot with 4 fruits

3.6 Sunight and serration of the leaf edge

representative series of Elstar

The serrations along the leaf edge change during the course of the season. The largest leaves in the rosette have clear, sharp serrations. Later in the season, the serrations become rounder and less clear. The serrations at the top of the leaf are sharper than those near the petiole. We initially assumed that the leaf edge would be more sharply serrated if more light was present. However, no differences were found between sun and shadow leaves. Neither was any difference found between any trees which were treated with a Biodynamic field preparations compound and those that were not (941209-POT-C efgh, unpublished). However, a difference was found in the leaf edge serrations between Elstar with normal vitality and the same cultivator with very weak growth caused by heavy root pruning. The heavy root pruning resulted in nitrogen deficiency and water stress. The serrations in this case were fine, sharp and had red points. On the untreated trees, they were large, round and green. These fine, red serrations can only be seen in the original series, for example 992408-BtLLW-Ed (not published here).

For most applications, serration of the leaf edge can be ignored when tracing.



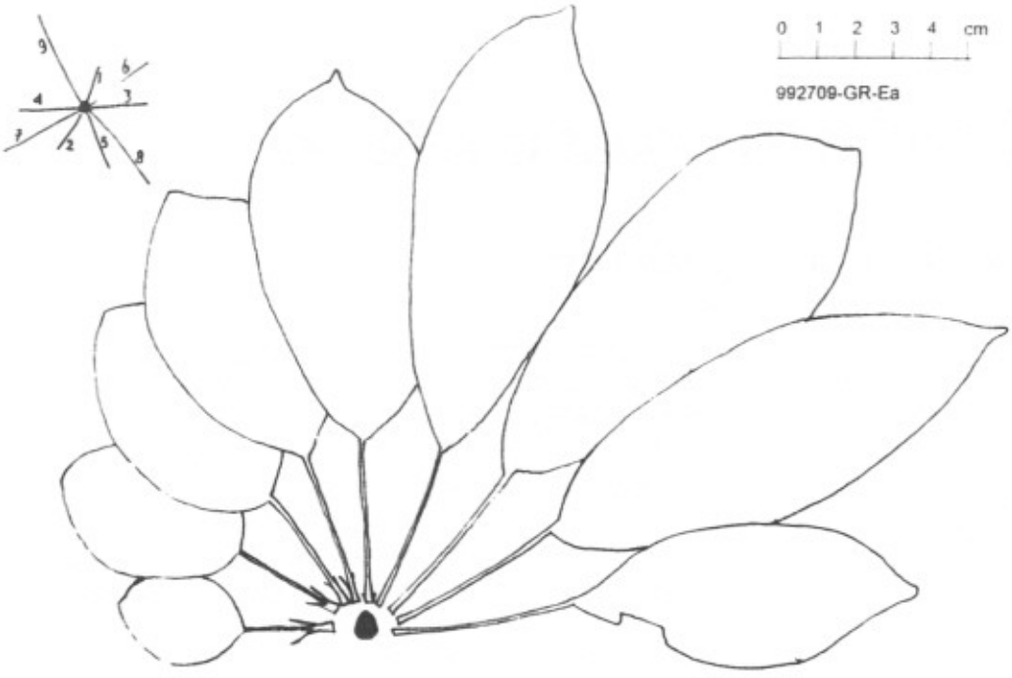
962609-TLB-Eb*: Only a few leaves were drawn with serrations

3.7 Leaf series from short shoots

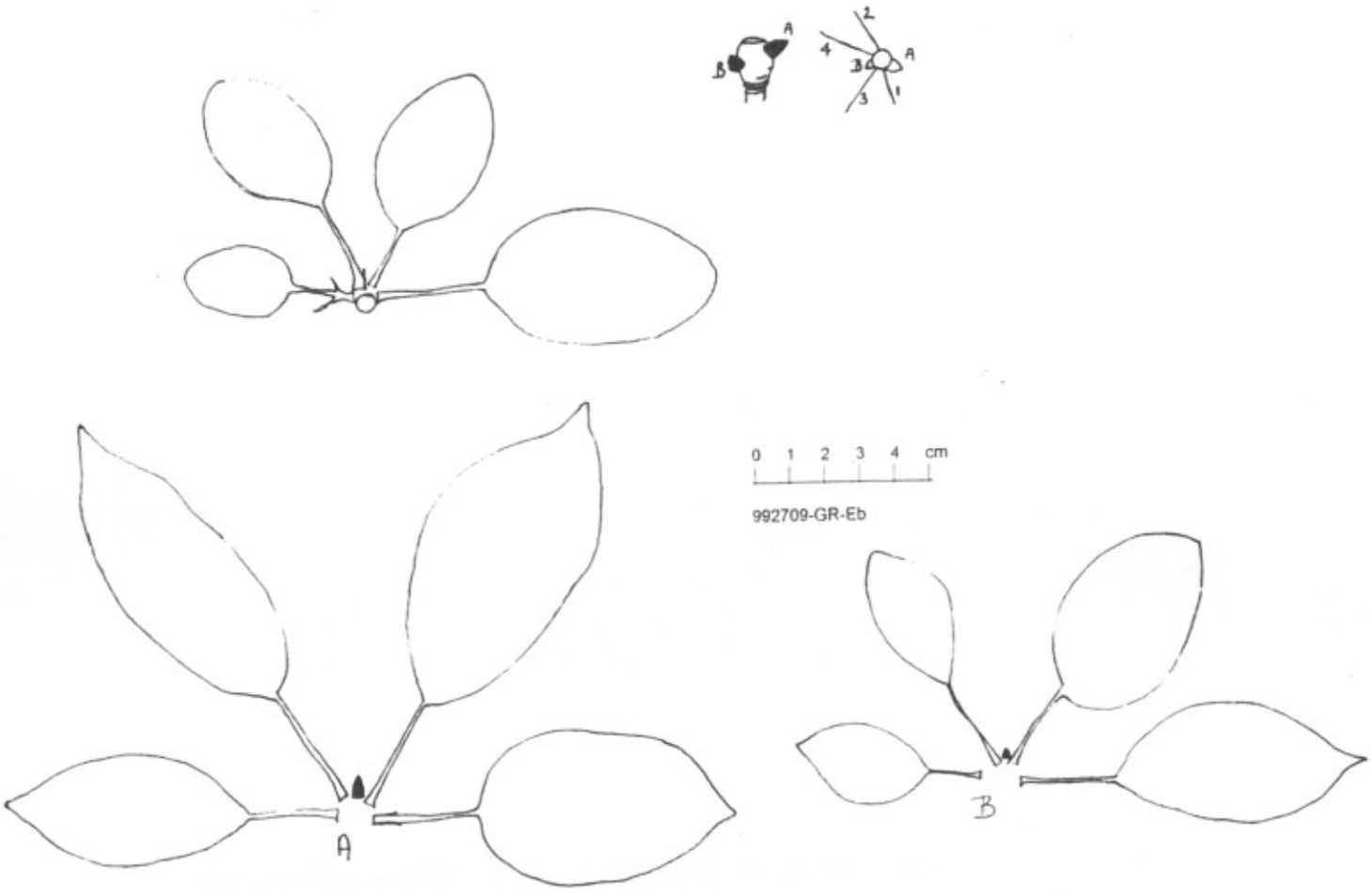
Leaf series as a picture of Elstar

Leaf series from short shoots are presented in a half-circle. The initial orientation of the sequence of the leaves is noted.

At the end of the season, mixed clusters can be found which have flowered and are carrying fruit, or had carried fruit (see open circle in centre), usually with only a few leaves. In addition, there are newly formed leaf clusters with many more leaves, with a terminal bud (terminal bud is drawn in black). Both can be found near a spur, see 992709-GR-Eb.



992709-GR-Ea: leaf cluster along vital, first-year wood at the end of the season.



992709-GR-Eb: Three clusters on a spur at the end of the season. The original mixed cluster with fruit stem scar is shown at the top. At the middle and bottom, the two newly formed leaf clusters with a moderate (A) and weak (B) terminal bud are shown.

4 Examples of applications in research

4.1 Mealy apple aphid with luxuriant growth

Leaf series as image of Elstar in connection with § 3.5

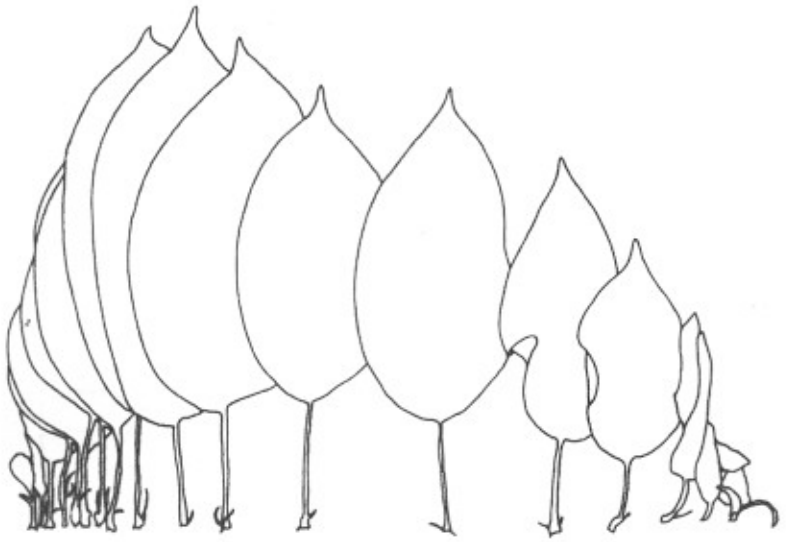
This shoot displays extreme vital force: enormous leaves and long internodes. Most shoots with a top infestation of mealy apple aphid show explosive growth in the first half of the shoot (see table). Most shoots without infestation by mealy apple aphid show more moderate growth (see § 3.5).

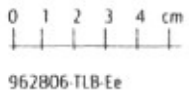
The new hypothesis which came about by viewing the leaf series was: a shoot with large leaves in May has a greater chance of later infestation by mealy apple aphid. The large leaves were not so noticeable on the intact shoots before the leaf series were made.

As a small experiment this idea was then tested on 40 shoots (see table). The shoots with growth inhibition by fruit bearing turned out to be least susceptible for a late infestation by mealy apple aphid. This hypothesis requires further support. The answer is important for the question about which type of growth (or which leaf series picture) we want to strive for in May to obtain both optimal fruit setting and few aphids.

Classification of growth and fruit bearing of 20 shoots with aphids and 20 without aphids.

Classification of shoots on 28 June 1996	explosive growth in May		moderate growth in May	
	0 fruit	1-3 fruit	0 fruit	1-3 fruit
20 shoots with aphid	15	3	2	0
20 shoots without aphid	0	1	3	16





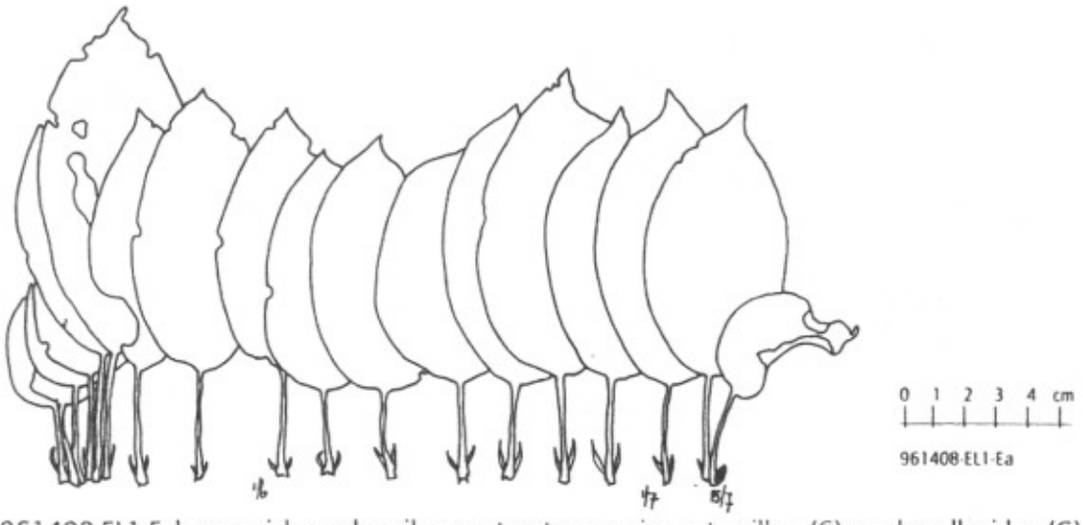
962806-TBL-Ee: shoot with no fruit, leaf curl caused by mealy apple aphid

4.2 Soil conditions

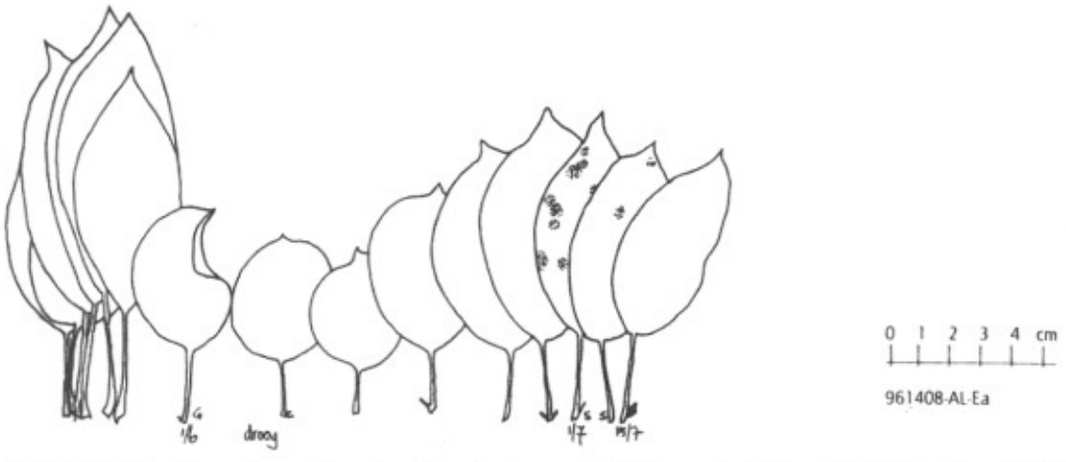
Leaf series as image of Elstar

It is striking that the leaves and stipules are larger on trees grown in sandy soil. This was also found with Jonagold (961107-FL5-Jab, unpublished).

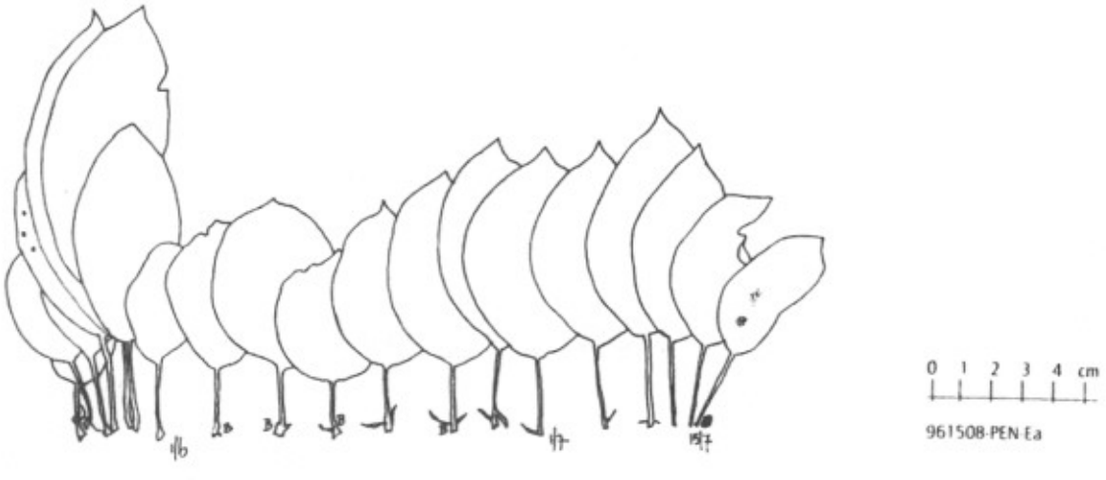
Water stress and/or wooly aphids can cause the leaves to be smaller. No unequivocal relationship was found between the leaf series and the N_{min} in the soil. The above leaf series with large leaves, for example, does occur on sandy soil with a high N_{min}.



961408-EL1-E: humus-rich sandy soil, no water stress, spring caterpillars (C), apple gall midge (G), one fruit, N_{leaf} = 2.7% (June) and 2.3% (August).



961408-AL-E: River clay soil, water stress in June, scab (S), one fruit N_{leaf}=2.3% (June) and 1.9% (August).



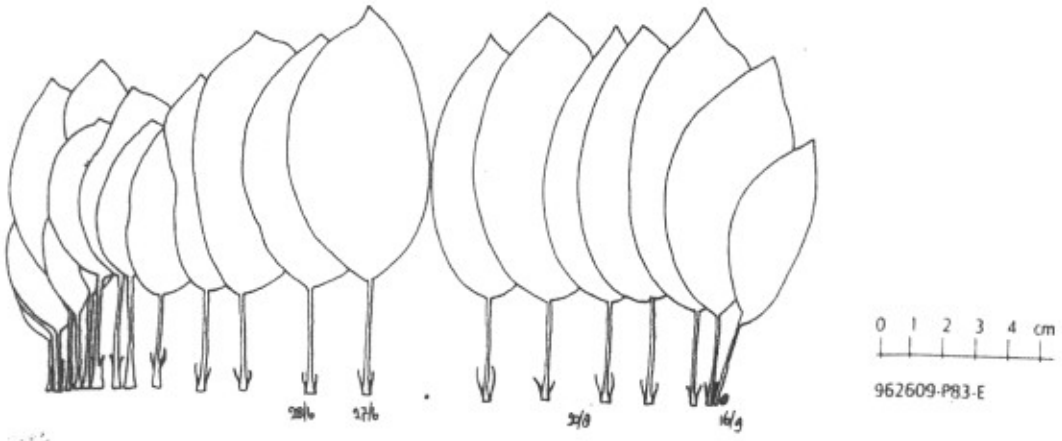
961508-PEN-Ea: River loam, wooly apple aphid in axillary buds (B), apple leaf gall midge (G), scab (S), one fruit, N_{leaf}=2.3% (June) and 2.1% (August).

4.3 Water stress

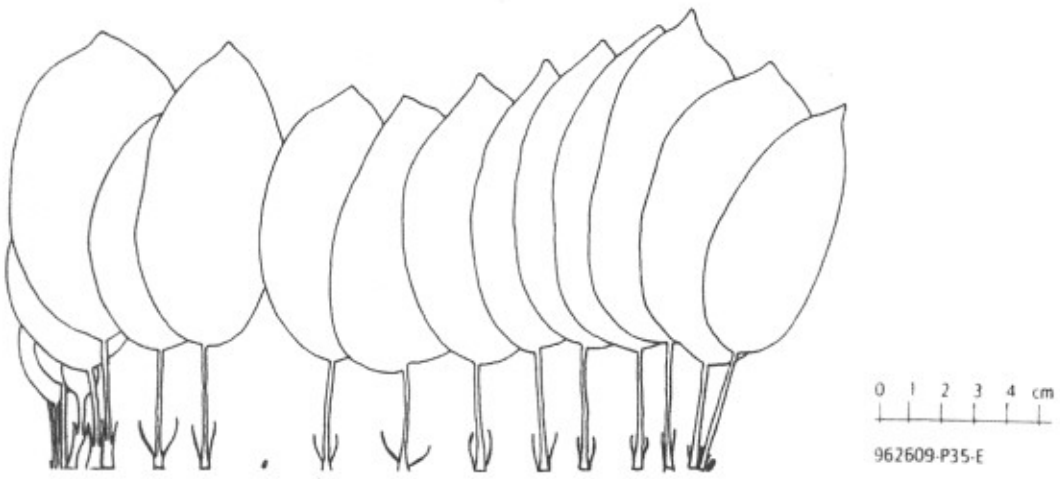
Series as image of Elstar in a pot test with serious water stress during various months
Due to the rich potting soil, these are well-fed trees with a high nitrogen content (all N_{leaf}>2.5% (August)). Pests and diseases were controlled with chemical controls. Also compare the series for Elstar in various types of soil in organic orchards in § 4.2. The period of water stress can be recognised by growth stagnation, very small round leaves with long, fasciated stipules and very short internodes. (More data from research of M. van der Maas, FPO, still unpublished)

Average shoot length in cm during the season

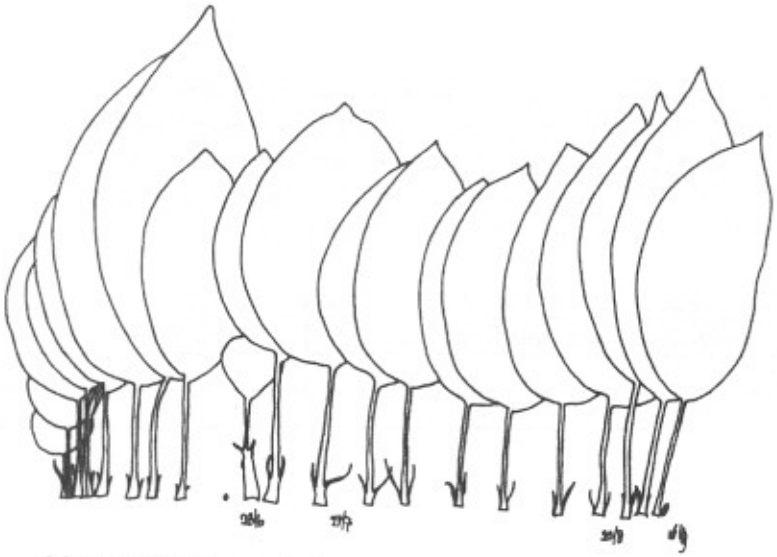
Pot tests 1996	28 Jun.	27 Jul.	20 Aug.	16 Sept.
No water stress	8	10	17	21
Water stress in May	4	7	13	15
Water stress in June	6	9	17	21
Water stress in July	7	9	12	18 regrowth!

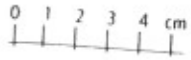


962609-P83-E: one fruit, no water stress



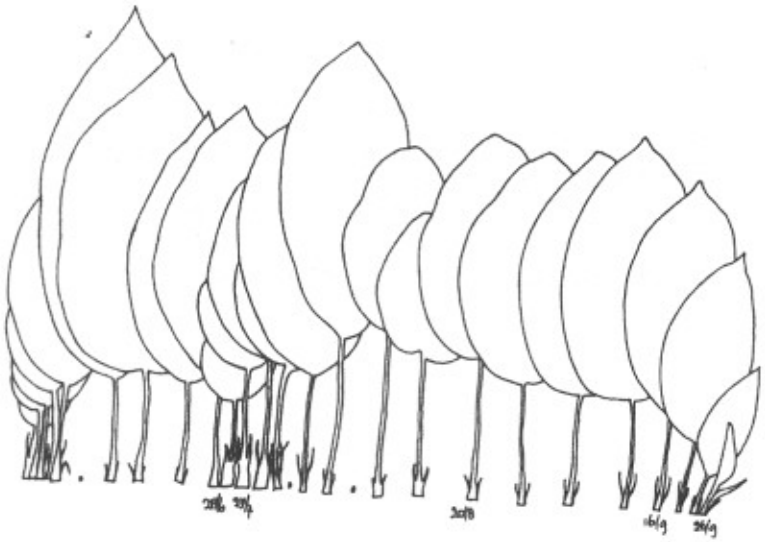
962609-P35-E: one fruit, water stress in May

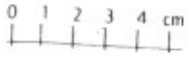




962609-P26-E

962609-P26-E: one fruit, water stress in June





962609-P72-E

62609-P72-E: one fruit, water stress in July

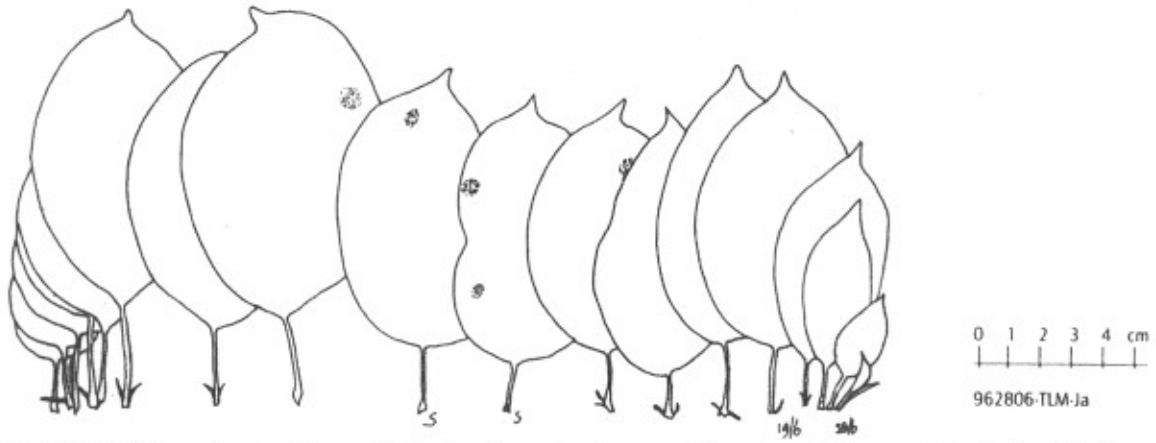
4.4 Growth inhibition by virus

Series as image of Jonagold

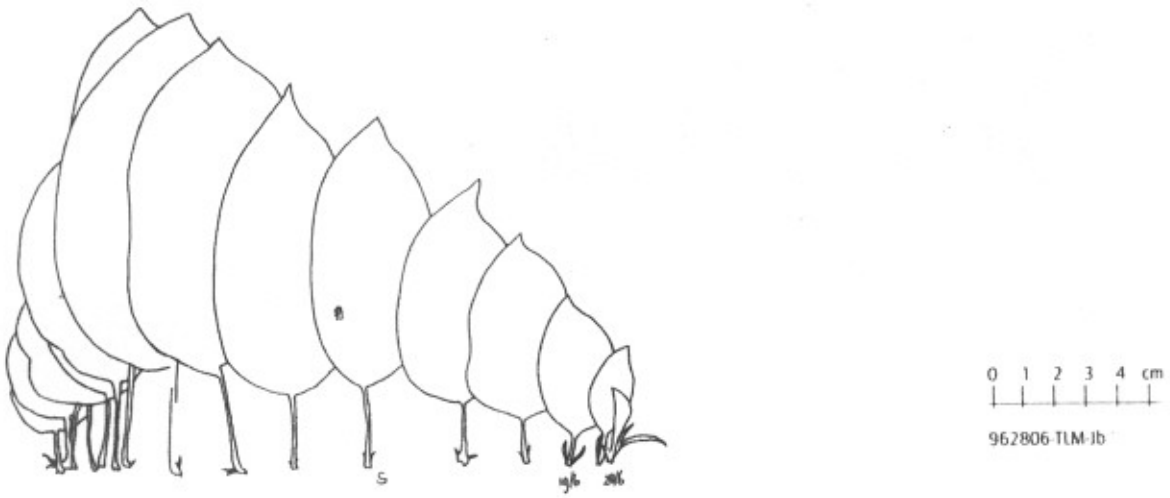
The great differences in vitality which had been noticed by the fruit grower were also visible in the leaf series. The virus-free trees grow more strongly and terminate their growth later. After four years they have a much greater tree volume, resulting in a higher gross yield. These vital trees are more susceptible to scab, however. After sorting the apples with fruit scab, the net yield is the same (see table). After growth control measures were taken during the following years, this difference disappeared (unpublished).

Difference in production and loss due to scab between trees with and without 'virus-free'-label.

4 year old Jonagold, 1996	kg/tree gross production	kg/tree fruit Class 1+2	loss due to scab
virus-free	15	11.6	20%
not virus-free	12	11.5	4%



962806-TLM-Ja: shoot with one fruit, virus-free planting stock Jonica on M9, great deal of scab (S).



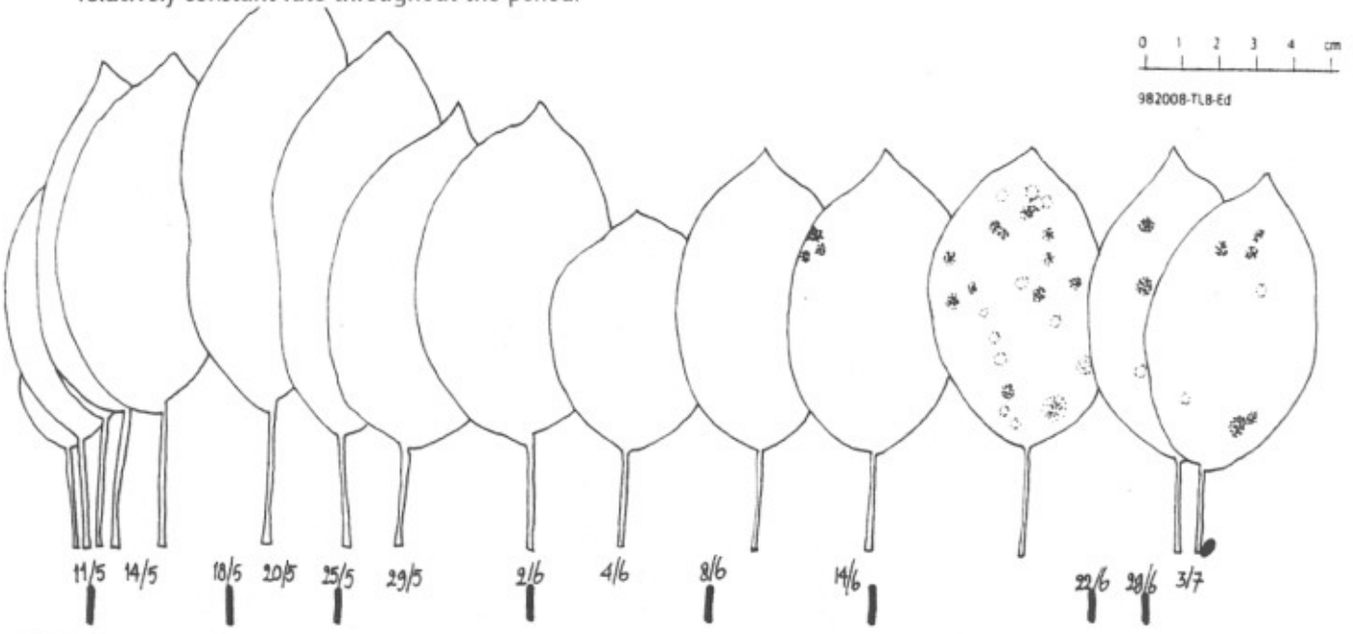
962806-TLM-Jb: shoot with one fruit, non-virus-free planting stock, Jonica on M9, little scab (S), N_{leaf}=2.7% (June) and 2.2% (August).

4.5 Scab development

Series as picture of Elstar

This series was made to evaluate the spraying scheme for scab control. The leaf series showed that scab infestation began in the middle of June. The infection period for scab is 2-3 weeks. The warning model for scab showed that there was an infection peak at the end of May. Also during this peak the crop was insufficiently protected. The peaks before this were properly protected.

Black dashes indicate periods of one week. This shows that approximately 1.5 leaves per week split off at a relatively constant rate throughout the period.



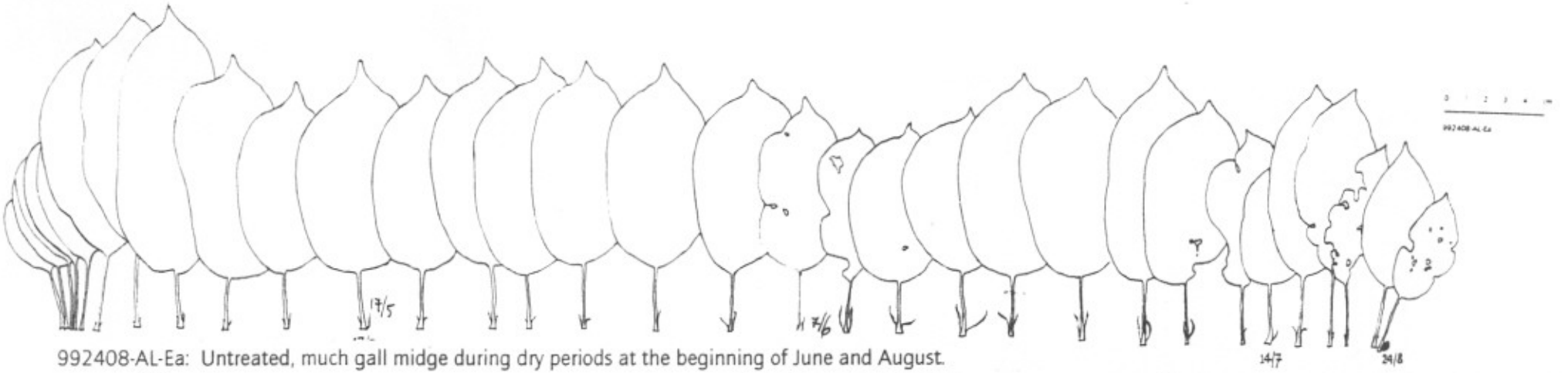
982008TLB-Ed: zero fruit, rain at the end of May, water stress at the beginning of June, the second half of June, strong growth and scab infestation, immediately followed by growth termination.

4.6 Measures for growth control

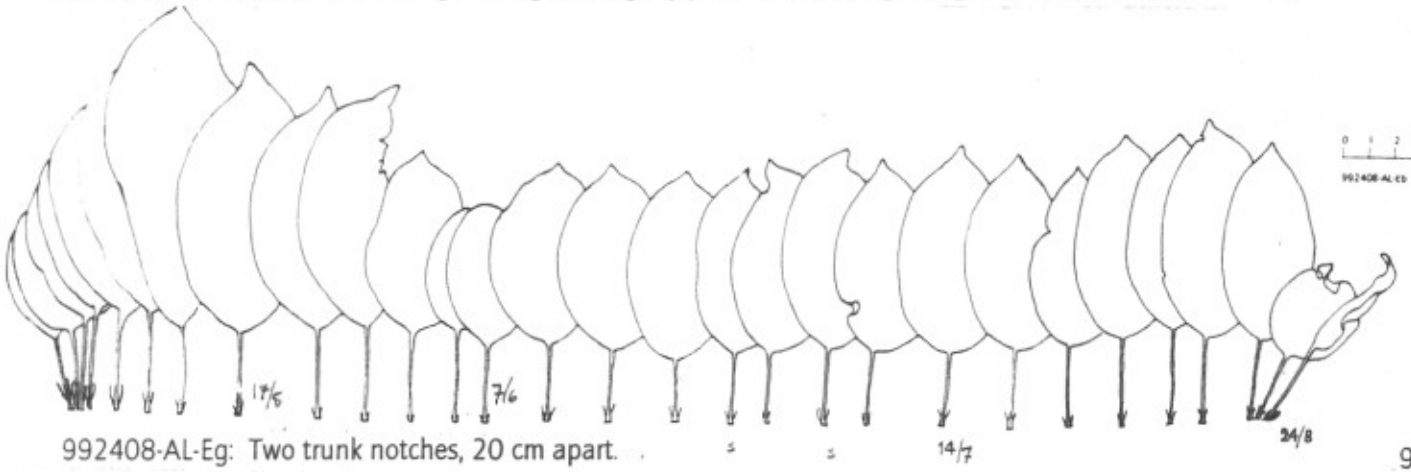
Series as picture of Elstar (see next page)

This series was made to study the influence of root pruning, root undercutting and trunk notching. In this orchard with fertile clay soil, this year was an alternating year without production. The vital growth was enormous, as can be seen in the untreated variant: large leaves that continued to emerge. Drought and gall midge in August brought an end to this.

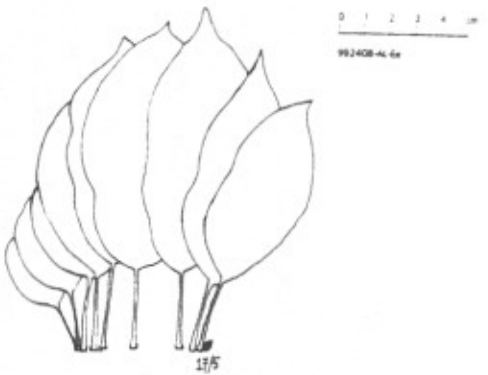
The root pruning and trunk notching slowed the growth somewhat (smaller leaves, shorter internodes), but not sufficiently. Due to both measures, the dry period at the beginning of June was clearly noticeable in the form of suddenly smaller leaves. Undercutting the root system with a root ball knife resulted in an enormous growth reduction. In this case hardly any long shoots developed, and the trees showed symptoms of deficiency. All variants were conducted with and without extra fertilisation. The fertilisation produced no difference in external characteristics such as shoot length, time of growth termination and disease development (those leaf series are not shown here). Leaf analysis did show higher potassium and nitrogen levels in the fertilised variants (nitrogen figures shown in table). In all series, the dry period at the beginning of June (smaller leaves) and in August (termination of growth) can be clearly seen. The series was standardised for zero fruit on a 10 cm long shoot growing vertically.



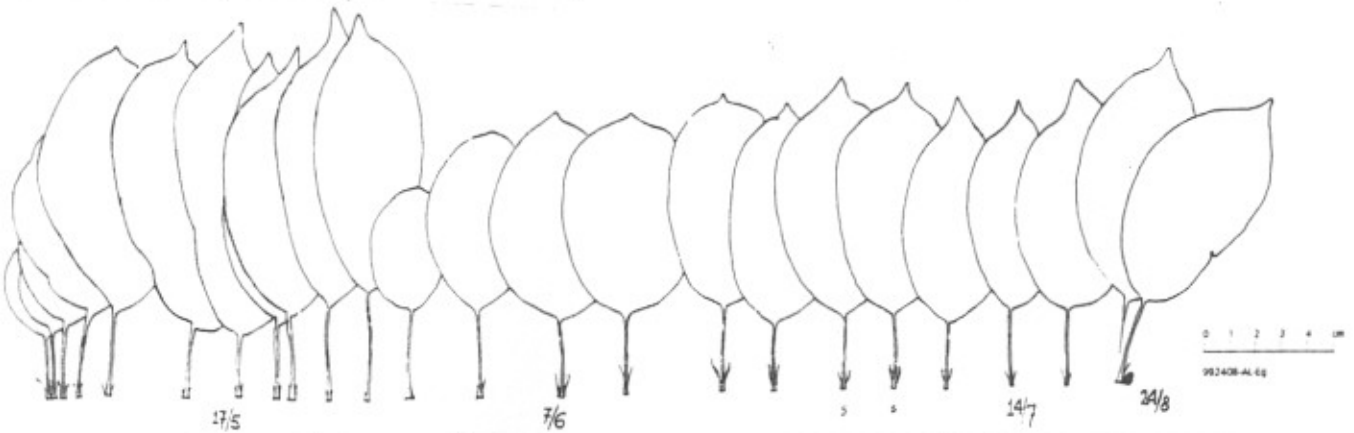
992408-AL-Ea: Untreated, much gall midge during dry periods at the beginning of June and August.



992408-AL-Eg: Two trunk notches, 20 cm apart.



992408-AL-Ee: Undercutting with root ball knife, 40 cm deep and 40 cm around the trunk.



992408-AL-Eb: Two-sided root pruning at 30 cm.

Nitrogen content of leaves in this trial

%N leaf analysis	9 June	14 July
Untreated	2.7	2.0
Root pruning without fertilisation	2.5	1.9
Root pruning with fertilisation	2.8	2.0
Undercutting	2.4	1.8
Undercutting with fertilisation	2.5	2.1
Trunk notching	2.7	2.1
Trunk notching with fertilisation	2.7	2.2
Target value	2.5	2.3

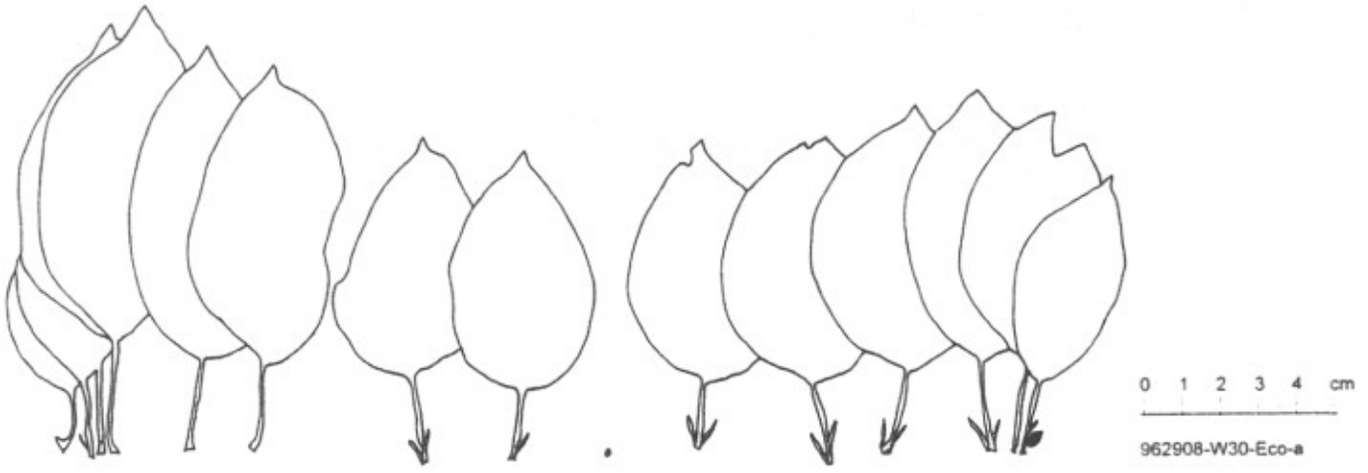
4.7 Influence of undergrowth

Series as image of Ecolette (see next page)

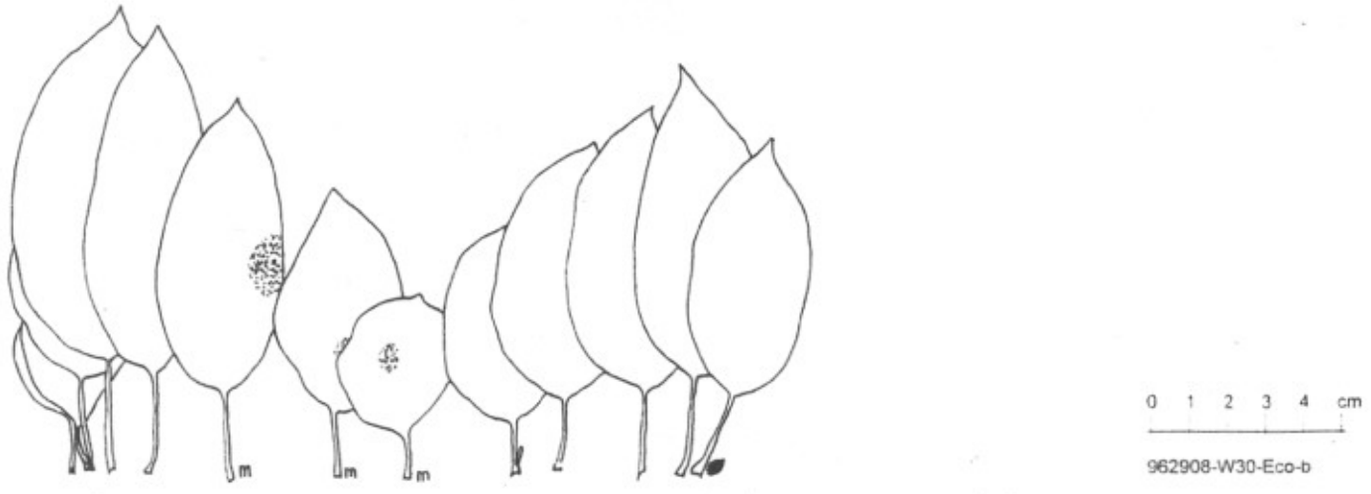
The objective of this study was to determine if it was possible to optimise the available nitrogen for the tree by using undercropping. The objective was to improve the fruit setting in the spring by releasing more nitrogen and promote good ripening in the late summer by releasing less nitrogen. In the variant which was completely weeded by hoeing, one can see that the growth was regular and continued for a relatively long period. In the variant with grass and clover growing under the trees, one can clearly see competition during a dry period in the summer and an early termination of growth. In the variant where a late summer undercrop was sown, there was more luxuriant growth in the spring and an early termination of growth. The analysis figures also show that the late summer undergrowth is able to transfer the available nitrogen for the tree from the late summer to the spring by fixing it temporarily in the undercrop. No significant difference was found in the nitrogen content of the leaf, nor was there a difference found in the total shoot length per tree due to the large variation in shoot growth (see 5 in the bibliography). There was no significant difference in average measured shoot length but various observers did agree about what a characteristic shoot for the object was. And there were clear differences between the objects as you see in these series.

Soil nitrogen and production by different soil management at the tree strip

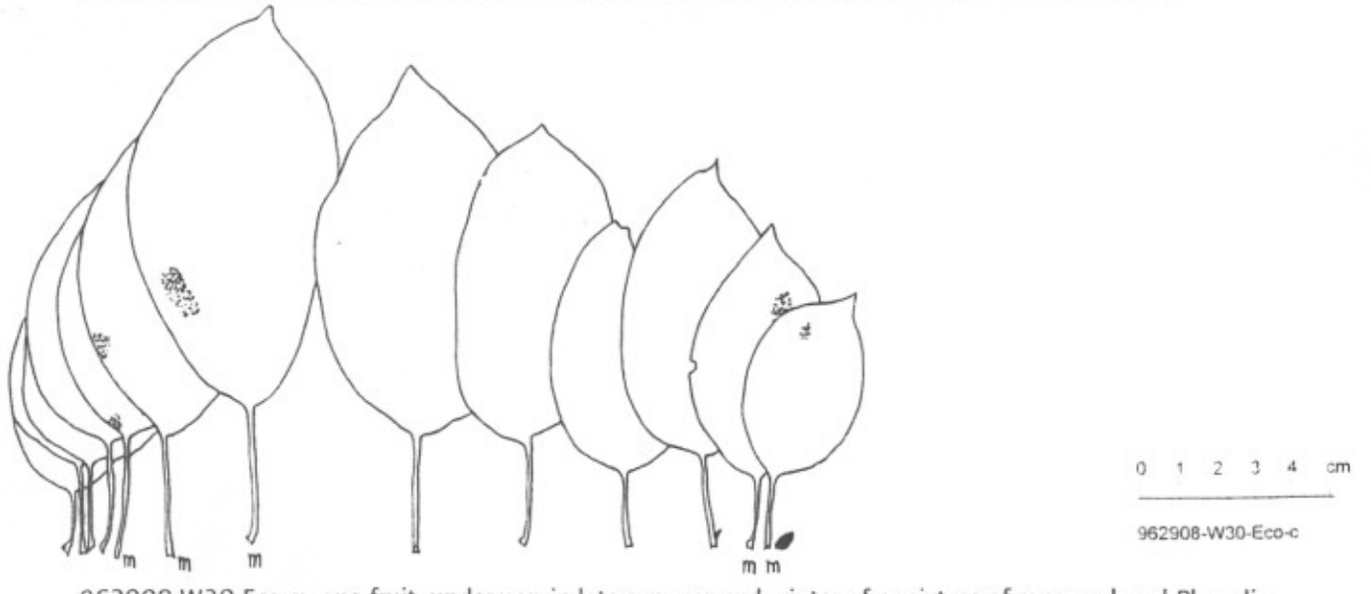
tree strip 1995 and 1996	soil nitrogen in ppm nitrate			production kg/tree		# flower clusters/tree
	Nov.'95	April'96	Sept.'96	1995	1996	1997
No undercrop all year	4.7 a	13.8 ab	3.2 a	4.0 a	8.0 a	141 b
Permanent grass+clover	5.4 a	10.3 a	8.1 c	3.7 a	5.7 a	94 a
No undercrop in Spring; August sowing of rape+Phacelia	2.3 b	17.0 c	1.0 a	3.5 a	7.1 a	145 b



962908-W30-Eco-a: one fruit, weeded soil under the tree, dot = missing leaf



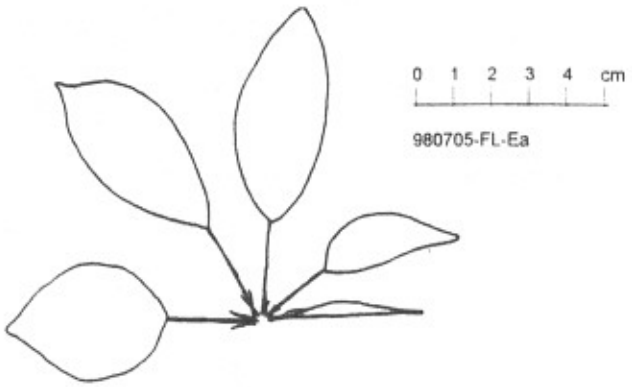
962908-W30-Eco-b: one fruit, permanent undergrowth with grass and clover; m = leaf miner moth



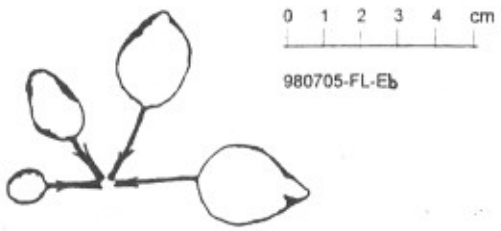
962908-W30-Eco-c: one fruit, undercrop in late summer and winter of a mixture of rapeseed and Phacelia.

4.8 Evaluation of leaf damage

Illustrative series of Elstar in study about the side-effects of chemical controls for scab
If leaf series of leaf clusters are made during flowering , these are much smaller than those taken from short shoots which have grown out at the end of the season (as in § 3.7). The differences between variants can already be significant and very obvious during flowering. With this example of copper damage, no difference could be seen later in the season in the leaf series taken from the grown-out shoots. The first leaves with black edges had then fallen off.



980705-FL-Ea: Untreated flower clusters during green flowering. On the right, folded leaf of a spur shoot which is ready to grow.



980705-FL-Eb: The same plot, here copper was sprayed just before flowering under cold, wet conditions; small leaves with black edges. No indications of a spur shoot.

5 Bibliography

1. Bloksma, J, 1991: Leaf Series as a Picture of Twig Growth/Blattentwicklungsserien zum Bild des Triebwachstums. Tagungsband 5. Internationaler Erfahringsaustausch über Forschungsergebnisse zum Oekologischen Obstbau, 1992, p.82-84.
2. Bloksma, J, 1992: Bladreeksen als beeld van de twijggroei: methode beschrijving. LBI Driebergen.
3. Bloksma, J, 1994: Vruchtzetting in de biologische fruitteelt. LBI Driebergen. (Elstar op M9 bij 6 verschillende telers eind juni 1993 en Elstar met verschillende bladbespuitingen, blz 16 en 17).
4. Bloksma, J, 1996: Mogelijkheden voor bodemverzorging in de fruitteelt vanuit biologische gezichtspunten. LBI, Driebergen. (blz 154 en 155 reeksen van 10 verschillende varianten bodemverzorging Elstar M9 proef Katzental LVWO; blz 152 reeksen Elstar M9 bij 4 verschillende bemestingsvarianten incl. stikstofbladanalyse en N_{min} in de bodem).
5. Schenk, A, H. Veijer, 1997: Betere stikstofvoorziening in biologische fruitteelt door ondergroei. Fruitteelt 32, p.14-15.