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Characterization of apple accessions for traits of relevance for organic agriculture

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Summary

The main goal of this research was to characterise the available apple accessions in the Netherlands, which will give a base for future breeding programs in the organic sector. Consumers increasing awareness about the environmental consequences of intensive farming systems led the demand towards more sustainable systems and healthier fruit production; resulting in the conversion of many apple orchards to organic standards (Peck et al., 2006). Organic farmers, nowadays, depend on cultivars which are well suited for conventional conditions (van Bueren et al., 2002). Tree architecture has a major role for organic apples growth and should be taken into consideration in apple breeding programs (Lespinasse & Delort, 1993). The common assumption among the organic sector is that many valuable traits, such as architectural traits, can be found in many old cultivars (cultivated before 1940) and should be integrated into future breeding programs. In order to provide the apple breeders with an accurate description material, an apple tree ideotype was first developed. Secondly, a methodology to assess the different traits was developed. The accessions were then evaluated according to the ideotype characteristics, and using the methodology developed previously. Eventually, the heritability of the most important traits was reviewed to complete the study and make it fully usable for further breeding purpose. According to tree ideotype study, which highlights the importance of tree architectural traits results, it is clear that conventional cultivars do not fit into the organic growers needs. However, the evaluation of the population using an improved methodology included a detailed scoring of fruit quality, tree architecture, diseases susceptibility and yield production, showed promising potential for future breeding perspective.

1.**Introduction**

1.1 General

Apple (*Malus x domestica Borkh.)* is one of the most important fruit crops in temperate zones worldwide (Jenick et al., 1996). Consumers increasing awareness about the environmental consequences of intensive farming systems led the demand towards more sustainable systems and healthier fruit production; resulting in the conversion of many apple orchards to organic standards (Peck et al., 2006). Organic farmers, nowadays, depend on cultivars which are well suited for conventional conditions (van Bueren et al., 2002). Many chemical treatments related to disease prevention (pesticides), tree architecture design (Induce branching chemicals) and yield production (chemical fertilizers) are being in use in conventional apple orchards, and therefore modern varieties' performance rely on high levels of chemicals. However, in organic apple farming these treatments are banned and in many cases farmers experience difficulties to adjust the organic management methods to the conventional cultivars. Therefore, it is essential for organic farmers to have cultivars which are suitable for the organic growing conditions in order to supply a product that compiles to the wishes of the consumers.

The worldwide tendency in apple breeding is to use only a narrow range of the genetic pool (Noiton & Alspach, 1996). Most breeding programs mostly choose the same cultivars ,'Golden Delicious', 'Red Delicious' ,'Jonathan' or 'Mc-Intosh', as parents for crosses with new hybrids (Durel et al., 1998). The main goals of conventional breeding programs are to increase fruit yield, upscale fruit quality and to achieve resistance to the main pests and diseases (Laurens, 1998). The main selection method is a simple mass selection (Durel et al., 1998). The consequences of these trends, while using only few cultivars, threaten to decrease apple genetic background diversity (Noiton & Alspach, 1996).

According to organic apple growers and researchers, the major requirements of a suitable cultivar for organic and low input systems are i) resistance to the main apple pathogens, ii) fruit quality, appearance and productivity and iii) tree architecture, which contributes largely to an enhanced yield in organic farming systems (Jansonius, Lateur and Vandewall, pers. comm., 2011). Many studies carried out in the organic apple sector have been focusing on disease resistance, but not much has been done to investigate other aspects of organic apple growing (Warlop et al., 2010). There is, thus, an urgent need for better adapted cultivars which can optimise organic apple production through displaying high resistance to major apple pests and diseases, combined with adequate fruit quality and an improved architectural structure.

The common assumption among the organic sector is that these valuable traits can be found in many old cultivars (cultivated before 1940) and should be integrated into future breeding programs. Those cultivars reflect the focus of breeding for fruit quality as it was before 1940, when intensive agriculture started to grow. Organic growers also indicate that other valuable traits such as tree architecture can be found in old cultivars.

Furthermore, the emotional value conveyed by old varieties to which consumers and growers appear to be sensitive, emphasize the need for a detailed description of those cultivars in regards to the mentioned traits. However, this description is not yet available to the public and would be precious to discuss for future breeding perspectives.

1.2 Objective

The main goal of this research was to characterise the available apple accessions in the Netherlands, which will give a base for future breeding programs in the organic sector. In order to provide the apple breeders with an accurate description material, an apple tree ideotype was first developed, taking into account the requirements of organic apple growers and researchers. Secondly, a methodology to assess the different tree architectural traits was developed. Indeed, as mentioned before, tree architecture has a major role for organic apples growth and should be taken into consideration in apple breeding programs (Lespinasse & Delort, 1993), but this approach is relatively new in breeding programs in the Netherlands and no precise methodology has been found to assess architectural traits accurately. The accessions were then evaluated according to the ideotype characteristics, and using the methodology developed previously. Eventually, the heritability of the most important traits was reviewed to complete the study and make it fully usable for further breeding purpose.

2. Tree ideotype description

The first step and aim of this study was i) to define traits of interest for organic apple growers and ii) to describe an apple tree ideotype suited to the needs of the organic sector in the Netherlands. In order to assess those traits, Dutch organic apple researchers, growers and breeders were interviewed. The research was completed by literature study.

2.1. Materials and methods

In summer 2011 a study was conducted, based on field trips and interviews of organic breeders, researchers and growers in the Netherlands and Belgium (Table 2.1). Additional information was added after interviews and field excursions at the pomological association in fall 2011. The study was completed by literature research.

Table 2.1 Interviews conducted for description of organic tree ideotype

Name	Description	Date
Anbergen Ron	Phytopathologist	16.09.2011
Hautman Henk	PVN apple collection curator	16.11.2011
Jans Jansonius Pieter	Organic fruit researcher and grower	18.07.2011
Lateur Marc	Organic fruit breeder and researcher	17.08.2011
Meijer Bertus	Fruit Researcher ,CGN apple collection curator	23.08.2011
Pelleboer Marten	NPV apple collection curator	16.11.2011
Vandewall Mart	Organic apple breeder and grower	20.07.2011

CGN=Centre for Genetic Resources, the Netherlands, NPV=Noordelijke Pomologische Vereniging, PVN=Pomologische Vereniging Noord-Holland

The apple tree ideotype presented here summarizes the main traits of interest to be taken into account according to the contribution of experts, and based on their knowledge and experience. Next to the interviews, the results were completed by a literature study. This description constitutes the basis for the methodology that was developed in a second stage to assess the accessions with an emphasis on the valuable traits for the organic sector.

2.2. Results

The tree ideotype traits can be categorized in three different groups, with the following hierarchy of importance: 1.) tree architectural traits, 2.) fruit traits (quality, productivity and appearance) and 3.) disease resistance.

Architecture

Designing an apple orchard should be associated with the growth style and the shape of trees, taking the limited space and working hours of farm management into account. Studies usually emphasise the importance of tree height, planting distance, alley width and leaf area index (LAI) in order to achieve good light distribution and therefore increase the orchard productivity. Especially for the organic sector minimal pruning is a desirable trait for many fruit growers, due to the labour costs and consumed time. Therefore, limiting the undesirable vegetative growth and direct the focus on fruit production is a priority trait for tree architecture, and for which genetic variability should be found (Lauri, 2008).

Besides high productivity, the relationship between the number of architecture characters (e.g. branching density, shoot growth etc.) and the development of diseases and pests may constitute an additional value of tree architecture. Open tree shape which allows more air circulation and light interception can significantly reduce the spread of diseases. A reasonable explanation for this is the reduction of the wetness periods (Simon et al., 2006). The genetic variability is considered to be very high in apple cultivars and great variability in tree architectural shape was recorded. The common classification of architectural tree type is divided into four groups according to tree growth, branch distribution and fruit position (Lespinasse, 1977).

Despite the strategy of most apple breeding programs to mostly concentrate on high productivity, fruit quality and disease resistance. It is important to note that tree architectural characteristics are significant and should be taken in consideration as well (Lespinasse & Delort, 1993). Growth habits and branching types affect both farm practices and yield production (Lauri & Lespinasse, 2010).

Tree architecture traits

Angles of the branches – The angles of the branches sprouting on the main trunk must be vertical to the trunk. The angles affect yield production to a substantial degree. Therefore it is a common practice for apple growers to create these angles by bending the branches and to end up with branch angles parallel to the ground. This practice consumes a lot of time which is precious for organic growers. The branches should be able to carry heavy loads of fruits and therefore be able to bend. Due to its effect on yield production and training practices the flexibility of the branches plays a major role (Lauri & Lespinasse, 2000).

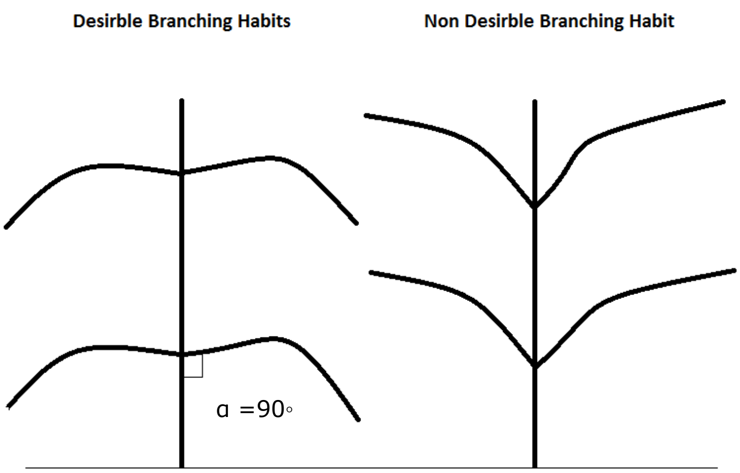


Figure 2.1. Desirable angles and flexibility of the branches

Adequate branches' distribution – A symmetric branching behaviour present in both, the top part and bottom part is desirable. The main pruning practice in the Netherlands aims at creating two centres of branches, the top and the bottom. This practice creates enough space for the fruits and leaves to be reached by the sunrays, which contributes to fruit quality. In addition, it increases the yield production. Organic apple growers are interested in having that trait as a natural growing habit because it is already present in conventional apple practices, but it is induced in early development stages in nurseries by chemical spraying, which is not desirable for organic growers and consumers. In addition, an adequate branching distribution and a growth pattern that creates enough space between the branches and the shoots may reduce diseases pressure (Lauri, 2008). Indeed, a reduced branching density creates bigger distances between growing shoots and provides larger amount of light and air to penetrate the canopy and, especially along the trunk. Thus it generates a dryer environment which helps to avoid pests and fungus.

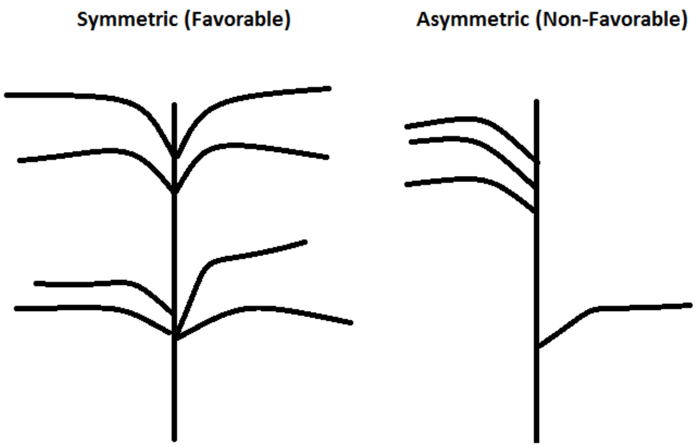


Figure 2.2.Branches' distribution.

Density of new buds and shoots on branches – A high density of new buds and shoots indicates a high fertility and ability for the tree to regenerate, whereas "bold" branches cannot produce enough fruits. However, growth of new shoots should be moderate in order to limit additional work pruning the shoots and to ensure high quality of fruits by creating enough space for the rays of light to penetrate all parts.

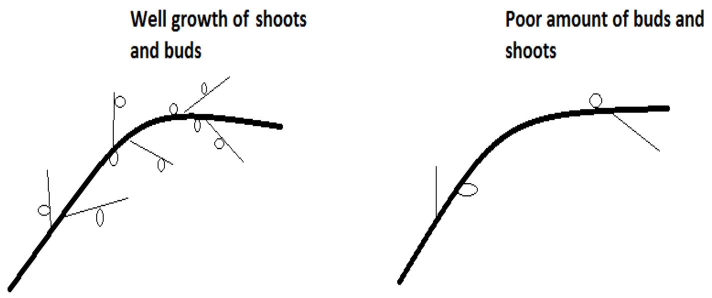


Figure 2.3. Appearance of shoots and buds on the branches.

Vigour control – The tree growth should be moderate and be balanced adequately between vegetative and non-vegetative growth. Therefore a vigorous tree with a very strong growth is not desirable, neither is a very slow growing tree (Lespinasse, 1992 & Laurens et al., 2000).

New shoots' growth – It indicates the ability for a tree to regenerate and to produce more fruits. The pruning method in the Netherlands aims at creating a top centre and bottom centre in order to make enough space for air and sun to reach all parts of the tree. At the beginning of winter it is possible to obtain a growth of new shoots form the past year, due the reason that pruning is done in the winter of the year before and there is no foliage on the trees. The new shoots that appear between the two centres are most likely to grow at the period after pruning.

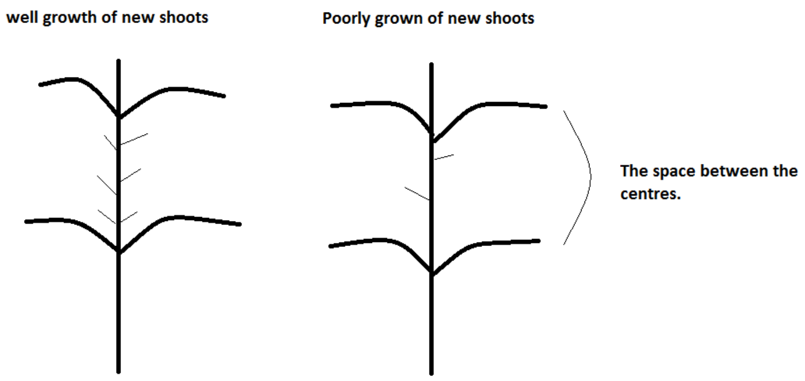


Figure 2.4. Growth of new shoots.

The ratio between the diameters of branches and the main trunk diameter – It reveals the tree balance and its ability to supply the branches, fruits and shoots with the needed amount of nutrients. The main trunk's diameter should be twice the branches' diameter.

Fruit quality, productivity and appearance traits

- Fruit storability is important to increase the length of marketability.
- Taste is the most important trait for the consumers. The organoleptic quality is a complex combination of sugar level, aroma, texture, acidity and firmness.
- Yield in low input conditions (organic) - High Nitrogen Use Efficiency (NUE) is a valuable trait. NUE is expressed as a ratio of output (e.g. dry weight or total N) to input (e.g. amount of N applied or amount of N captured) (Masclaux-Daubresse et al., 2010). Varieties that have a high NUE might have dark green leaf colour in the same conditions while other varieties have a dull green colour. The leafs colour can give an indication about the Nitrogen Use Efficiency.
- 'June fall' – At the beginning of the summer many flowers and fruits fall from the tree. In conventional agriculture those traits can be manipulated by artificial chemical treatments.
- Stable fruit production – The tree should be able to produce the same amount of fruits every year. It is known that some accessions suffer from biennial life cycle which cannot match the organic growers wish.
- Appearance – the colour, size and shape of the fruit are important for the consumers. The size and shape are also important for storability and transportation.

Disease and pathogen resistance

The major diseases are scab, mildew and canker. The main pathogen is the pink aphid.

Apple scab (*Venturia inaequalis*), powdery mildew (*Podosphaera leucootrich*) and canker (*Neonectria galligena*) are the major pathogens recorded in the Dutch apple orchards (Mitre et al., 2010 & Jansonius, pers. comm., 2011).

Apple scab, a fungal pathogen, can significantly reduce the yield production and damage the fruit appearance. The present treatments in conventional systems used to prevent and eradicate the negative effects of the scab are difficult to apply due to the narrow time window of fungicide effectiveness. Therefore the strategy, for conventional apple growing as well as for the organic sector, is to develop resistant cultivars which reduce the dependency on chemical sprays (Bus et al., 2002).

In 2010, Van Treueren evaluated 695 apple accessions from eight Dutch collections for their resistance genes to apple scab. Many breeding programs use Marker Assisted Selection in order to ensure that the progenies resistance. Scab has been targeted as a major pathogen in the Netherlands and therefore Dutch varieties show relatively high resistance to this fungus, compared to other varieties cultivated worldwide (Bus et al., 2002).

Canker, caused by the fungus Neonectria *galligenam*, can lead to death in buds, branches, spurs and shoots, and in severe situations where the trunk is infected, the whole tree has to be removed. Canker damages apple orchards in temperate and high average yearly rainfall zones, where humid micro climate induces the fungus reproduction (Beresford & Kim 2011).

There are no chemical prevention treatments allowed against canker according to the Dutch law for both organic and conventional growers. The practical strategy to handle this disease is by removing susceptible parts of the tree and when the main trunk is girdled by canker, the whole tree has to be removed (Meijer, pers. comm., 2011).

Powdery mildew is caused by the fungus *Podosphaera leucotricha*. Most cultivars worldwide are susceptible to this disease. Large amounts of fungicides are applied to control the spreading of this pathogen (Wan & Fazio 2011). The common strategy in organic apple orchards to overcome this pathogen consists in applying sulphur, lime sulphur and bicarbonate (Trapman & Jansonius, 2008).

Molecular markers are available to identified major resistance genes against powdery mildew and are currently used in many Markers Assisted Selection breeding programs (Dunemann et al., 2007).

An apple cultivar performing resistant to those pathogens, which combines a suitable tree architecture, as well as appropriate fruit quality (yield, taste, appearance etc.) and performs good in low input conditions are the main characteristics organic apple growers are looking for. In the organic sector many research projects have been focusing on disease resistance (Warlop et al., 2010), thus there is an urgent need for better adapted cultivars to optimise organic apple production.

In summary, an organic cultivar must be resistant or tolerant to various diseases mentioned previously, because of the prohibited use of synthetic pesticides and fungicides. For both powdery mildew and scab, which can damage apple orchards tremendously, an existing chemical treatment is allowed for conventional farmers. For the organic apple growers, the available organic substances and the common practice are expensive, time consuming and not sufficient. Therefore the development of a cultivar displaying a durable resistance/tolerance to those diseases should be prioritized.

Canker is treated in the same way in both conventional and organic farming systems. The common practice is to remove infected parts and in some cases, when the infection is severe, the whole tree has to be removed. In that case, the interest in developing a cultivar resistant to canker is common for both sectors.

3. Developing methodology to assess the apple accessions according o plant tree ideotype description with emphasis on tree architecture.

Based on the tree ideotype study the need for a special traits assessments was emerged. Apple tree breeding efforts in the Netherlands have been mainly directed towards fruit traits improvement (production, appearance and quality) and disease resistance. However, the interviews performed with experts in the field of apple growing as well as the literature study stressed out the need for more in-depth investigation of tree architectural traits. Such an evaluation has not yet been carried out yet in the Netherlands and thus the development of a methodology to assess those traits was necessary.

3.1. Materials and methods

In August 2011 several interviews were conducted with experts (cf. table 3.1) and focused on developing a methodology to assess the Dutch apple tree accessions on their architectural traits, fruit traits (production, appearance and quality) and disease susceptibility.

Table 3.1 Interviews conducted for developing a methodology to evaluate apple accessions

Name	Description	Date
Anbergen Ron	Phytopathologist	16.09.2011
Elk van Pieter	Former apple grower and member of PPO	26.10.2011
Lateur Marc	Organic fruit breeder and researcher	17.08.2011
Meijer Bertus	Fruit Researcher ,CGN apple collection curator	23.08.2011

CGN=Centre for Genetic Resources

PPO= Applied Plant Research: Fruit Sector

Fruit traits (production, appearance and quality) – The evaluation methodology was chosen according to international standards as described by M. Lateur (2010) and to current use in PPO (Applied Plant Research: Fruit Sector), Randwijk. The methodology is briefly explained in part 4.1.

Disease susceptibility – The method of evaluation for the three main apple diseases in the Netherlands (scab, canker and powdery mildew) was based on the tree ideotype. The symptoms were defined by Bertus Meijer (powdery mildew and canker) and by Ron Anbergen (scab).

The methodology for the scoring of disease susceptibility was based on Letour (2010) and briefly described in part 4.1(Lateur, 2010, Meijer and Anbergen, pers. Comm., 2011).

Tree architecture traits – The methodology for tree architecture evaluation was developed based on a literature study and an interview with Marc Lateur, who shed light on international criteria for tree architecture evaluation. The methodology development was completed with Bertus Meijer and Peter van Elk (PPO) and adjusted to the style of apples farms as it is grown in the Netherlands. The scoring methodology was based on the Eufrin scores for traits like vigorous and further developed for branching, shoots and buds habits together with Bertus Meijer and Pieter van Elk (PPO).

3.2. Results

The methodology for tree architecture evaluation elaborated according to the international standards (Eufrin, 2011) based on Lespinasse (1977) is presented in table 3.2 and briefly described in appendix I. It was not possible to apply this method, because the trees of the CGN collection were planted in 2008 whereas this method assesses at least 10-year-old trees. Moreover, another factor that influenced the choice of a different methodology was the practical issue. The implication of a methodology that was described only by literature and not according to practical experience of a personal communication creates difficulties in understanding the precise definition of criteria. Furthermore, additional traits that were not included Lespinasse's four categories arose during the interviews, and showed to be crucial and should not be missed. Traits such as symmetry distribution of branches, density of buds, growth of new shoots and the ratio between the main trunk and the branches were not included in the Eufrin architecture descriptor. In summary, it is important to evaluate the trees according to international standards to obtain clear results that can be exploited by a broad range of potential breeders or other individuals interested in these accessions. Considering that this study aims at giving a deeper sight on the Dutch accessions for future organic apple breeding program in the Netherlands, the methodology for tree architecture evaluation was largely adapted to fit the need of local organic apples researchers and growers and therefore aims to reflect their specific interests. The final methodology is briefly described in section four, the tree ideotype. The main tree diseases of apples in the Netherlands (Scab, Canker and Powdery mildew) evaluation methodology was chosen beside on the interviews study. The symptoms were defined by Bertus Meijer (Powdery mildew and Canker) and By Ron Anbergen (Scab). The Methodology of the scoring of disease susceptibility was based on Lateur, 2010 and briefly described in part 4.1 (Lateur, 2010, Meijer 2011 and Anbergen, pers. comm., 2011).

Table 3.2 Eufrin methodology to define tree architecture

Type	Cultivar reference
I	"Spur" (Starkrimson) -1W:type 'Wijcik McIintosh'
II	'Reine des Reinettes', King of the pippins'
III	‘Golden Delicious'
IV	‘Granny smith'

Eufrin, 2011. Based on Lespinasse, 1977. (Briefly described in appendix I)

4. Apple accession evaluations and compression based on their genetic Background.

In order to assess apple cultivars with valuable agronomic traits for the organic sector, the apple CGN(centre of genetic resource, the Netherlands) collection was chosen as the main resource. The CGN apple collection is located in Randwijk, Gelderland and consists of 202 accessions. The gene collection is maintained as trees in an orchard by Applied Plant Research: Sector Fruit (PPO).

The history of this collection consists of a few cycles and kept on moving to different locations before it was established at Randwijk in 1998. The original purpose was to find genes involved in scab and powdery mildew resistance in the old varieties and to understand the heritability of important agronomic traits.

In order to achieve durable resistant cultivars a QTL analysis was carried out to identify loci associated with scab and mildew resistance. However, for canker resistance, only partial observations were recorded and limited analyses were carried out. Later, because of the risk related to biodiversity reduction due to the increasing usage of genetically modified trees, a decision to protect varieties with valuable, extreme traits was taken in order to preserve a large pool of genes (CGN, 2012; Meijer, pers. comm., 2011).

Next to the CGN the other sources for apple collections in the Netherlands are the Pomological associations which are non-governmental organizations (NGOs).

The pomological associations aim at collecting known varieties that have been grown in the region of the association and some varieties that were cultivated in the neighbouring countries that have been used in the region as well. Many cultivars have been developed in the Netherlands during the last centuries. The Netherlands have a rich history of apple cultivation with a large diversity developed in the country. In 1758, Knoop described around 300 varieties that were grown in the Netherlands at that time. The tradition of growing and developing apple cultivars is part of the Dutch agriculture heritage. After the Second World War the type of agriculture changed from the small scales – constituted by apples production mixed with other on-farm agricultural activities - to large scales defined by intensive apples orchards with high density of trees and production oriented.

In the process, only the cultivars that were adapted to the new practices were conserved and the old traditional cultivars were abandoned (Van Treueren et al., 2010).

The old varieties (cultivated before 1940), however, present many interesting traits for breeders and have emotional value for many apple growers and consumers. In addition to the importance of maintaining the gene pool the pomological associations started to create collections which reflected the regional breeding and growing apple tradition. The difference between the pomological association's collections regrouped cultivars that were suited for different growth practices, as trunk height, rootstock type and pruning style, and the preference of local farmers and consumers (Pelleboer and Hautman, pers. comm., 2011). The wish to reflect the regional tradition has led the collections to differ from each other and therefore the variability in the varieties that can be found between the different collections is large (Van Treueren et al., 2010).

The last step and goal of the project focuses on assessing the accessions according to traits that have been defined and giving a deep insight on the Dutch apple varieties and the varieties that has been in use during the last centuries. The major sources to assess Dutch accessions are the Centre for Genetic Resources, the Netherlands (CGN), Pomologich Vereniging Noord Holland (PVN) and the Noordelijke Pomologische Vereniging (NPV). Additional evaluation and comparison was made using data collected by the CGN in 1999 and 2007 (data supplied by Bertus Meijer, curator of the CGN collection) and by Bloomers 1983.

4.1. Materials and methods

4.1.1. Study material

In 2011, 202 different apple accessions, mainly Dutch cultivars, from the CGN apple collection were phenotyped and scored for disease resistance, fruit quality, production, and tree architecture. In addition, 24 accessions from Noordelijke Pomologische Vereniging collection and 21 accessions from Pomologische Vereniging Noord-Holland collection were observed and scored for architectural traits.

Centre for Genetic Resources, the Netherlands (CGN), Randwijk, Gelderland

The CGN apple collection was chosen as the main material for evaluation because it displays a great variety of Dutch oriented cultivars which could be identified with some certainty. It is located in Randwijk, Gelderland and consists in 202 accessions. The collection's main goal is to maintain the Dutch apple cultivars. However, in the past years curators decided to add to the collection cultivars with valuable traits originating from other countries. In order to examine and understand the main traits relevant to organic agriculture the accessions were compared base on their genetic background factors. The two main factors with available information were year of cultivation and origin country of the cultivation.

The distribution of accessions according to their country of origin and the year of cultivation are presented in table 4.1a,b, and the distribution of the Dutch collection according to their province of origin is shown in figure 4.1. All accessions were grafted on rootstock M.9, which confers low vigour, maintains a short juvenile period, and substantial productivity on low vigorous rootstock (Segura et al., 2006).

The current trees were planted in 2008 (replanted every 10 years on a fresh soil). Three trees per accession were planted. In some cases, trees had to be removed due to severe disease damage. The orchard was considered to be conventionally managed under the Dutch regulations (Meijer, pers. comm., 2011; CGN, 2012).

Noordelijke Pomologische Vereniging, Fredriksoord(NPV), Drenthe

The trees of pomological association collection in Fredriksoord were planted in 1995 and consists of 300 apple trees. The style of collecting the accessions is random and is generally made by members who plant their own favourite variety. Therefore, the certainty about the identification of some accessions may be doubtful. Some accessions have been replicated twice or even multiple times due to the collecting strategy previously mentioned. However, in 2004 100-120 trees were identified through DNA checks. Therefore only 24 accessions were chosen in this study, based on the certainty of their identification and their Dutch origin. The orchard is managed organically and according to the Dutch regulations. The pruning technique and management practices were different from the other collections. The trees were grafted on MM106 rootstock which is considered as a “high trunk” growing style. This practice reflects the traditional methods of apple tree management, which is suited for gardens and small extensive farm management (Pelleboer, pers. comm., 2011; NPV, 2012)

Pomologische Vereniging Noord-Holland (PVN), Middenbeemster, Noord-Holland.

The association was founded in 2002 and the first step was to establish a collection which was representative of the regional tradition in apple trees cultivation. According to the collection curator there was high certainty in the accessions’ identification. However, there was no D.N.A check for all accessions and the identification of some accessions was still questionable. Accessions from Pomologische Vereniging Noord-Holland collection were chosen for evaluation based on the same reasons as for the accessions in the Noordelijke Pomologische Vereniging collection. The orchard was organically managed, and also exhibited a unique pruning technique and management practices that reflect the regional pomological growth traditions. The cultivars were grafted on the M111 rootstock which allows a moderate but still higher than the conventional growth, as it is in practice nowadays on commercial apple orchards (organic and conventional) (Hautman, pers. comm., 2011; PVN, 2012).

Table 4.1.a Accession distribution according to their country of origin (CGN collection).

Country of origin	Number of accessions
Likely Netherlands[1]	100
Netherlands	58
Kazakhstan	19
Belgium	6
France	5
Great Britain	5
Germany	2
USA	2
Canada	1
Czech republic	1
Japan	1
Latvia	1
New Zealand	1

[1] Most likely to be Dutch origin although it is not certain

Table 4.1.b Distribution of the accession according to their origin regarded to the year of cultivation at the CGN collection

Origin of accession	Likely Netherlands[1]	Netherlands	Worldwide	Total (Year of cultivation)
# Accessions bred before 1940	7	27	12	46
# Accessions bred most likely before 1940[2]	91	24	26	141
# Accessions bred after 1940	2	7	6	15
Total (origin of cultivation)	100	58	44	202

[1] Most likely to be Dutch origin although it is not certain.
[2] Most likely bred before 1940 although it is not certain.

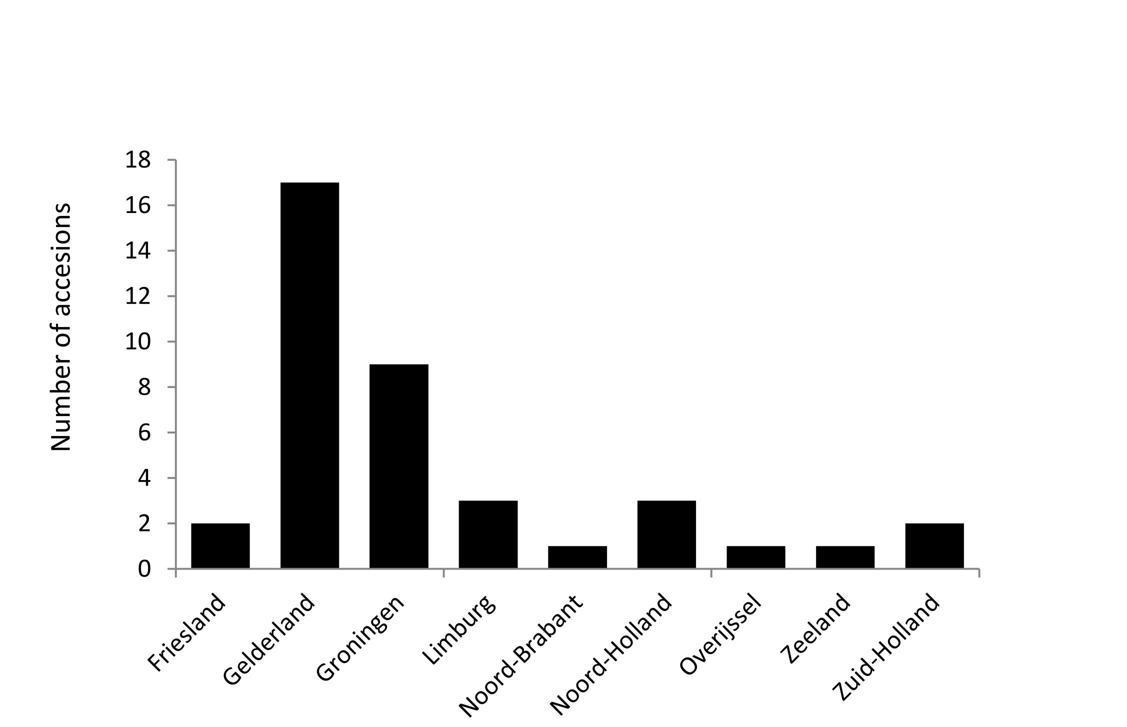


Figure 4.1. Distribution of the Dutch accessions by provinces in the CGN collection. (CGN website, 2012).

4.1.2. Accession evaluation

Fruit data (quality & yield production)

In September 2011, 202 accessions were evaluated for fruit quality and yield production at the CGN collection .The accessions were harvested and the fruits were evaluated in the laboratory of PPO in Randwijk. Five fruits per accession were harvested in different parts of the tree and on different trees, if it was possible (in cases of no or low fruit production it was not possible to harvest five fruits). Ornamental cultivars were excluded (21 ornamental cultivars). The choice of descriptors for fruit evaluation was based on Lateur's work (2010) and on PPO's internal scales. Those methods were taking international standards into account.

Base Colour: The base colour of the fruit was classified into three different groups (orange, yellow and green). Based on the Eufrin's descriptors list (table 4.2). However, not all the colours of Eufrin's list were easy to recognize and therefore the base colours were categorized in three groups only.

Table 4.2 Base colour categories

Category	Ground Colour
1	Red
2	Orange
3	Cream-White
4	Yellow('Golden Delicious')
5	Green Yellow ('Cox Orange Pippin')
6	Green ('Granny Smith')

Over colour: comprises five different categories (red, red-purple, purple, brown and orange). The method to assess the colour was unlike the methodology suggested by Eufrin due to different colours obtained in practice.

Over colour %: The cover percentage of the over colour on the fruit (over colour area/fruit area*100).

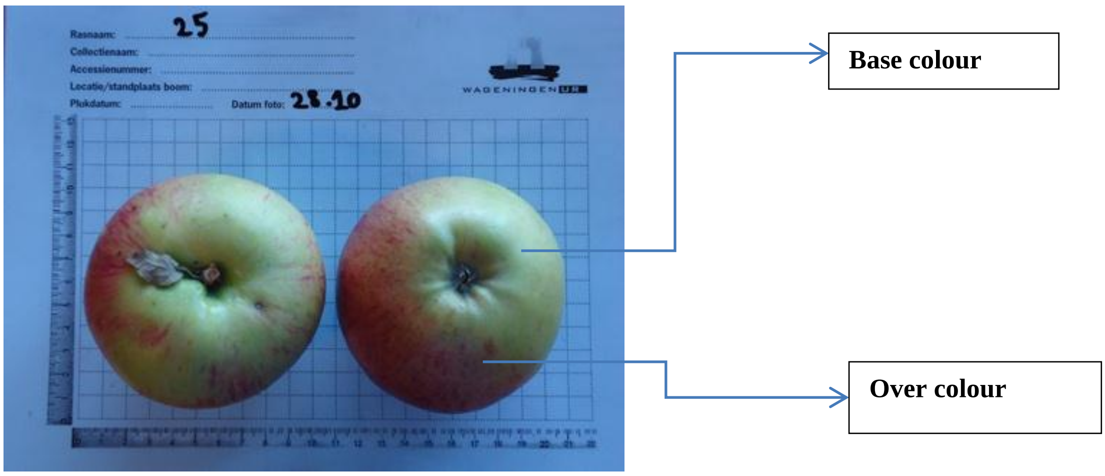


Figure 4.2. Demonstration of base colour and over colour.

Shape: the assessment was based on the PPO methodology to assess apple fruit shape (appendix II. Eufrin, 2011).

Fruit size (mm): Fruit were measured for their diameter according to the PPO Method.(Eufrin, 2011).

Table 4.3.Fruit size descriptor

Fruit size Level	Fruit size Diameter(Mm)
1	<45
2	45-50
3	50-55
4	55-60
5	60-65
6	65-70
7	70-75
8	75-80
9	80-85
10	85-90
11	90-95
12	95-100
13	100-105

Figure 4.3 .The frames used for fruit size assessment.

Brix: Sugar level was determined by brix. The measurements were done by Refractometer, Atago ATC-1 Brix 0-32%.

Yield (0-5): The evaluation was made by estimating the fruit load on the tree and on the ground. The estimation was made by observation of the total cover of the apples as a percentage of the green leaf area. In order to assess the yield production in kilogram, one tree from each category was chosen as a reference to assess the average yield per category (Kg fruit/ Tree).

Table 4.4. yield scale in Kg/tree

Yield Scale	Kg/tree
0	0
1	1-5
2	5-10
3	10-15
4	15-20
5	20-25

Fruit drop %: was calculated as the estimated percentage of fruit on the ground out the total number of fruit (ground + tree) (cf. Table 4.5). This measurement can indicate the period of the optimal time for harvest. Hence, early cultivars will have a high percentage of fruit drop (based on Elstar as a reference which is harvested on the mid of September)

Table 4.5.Fruit drop scales in %

Fruit drop categories	Fruit drop %
1	5%
2	10%
3	20%
4	30%
5	40%
6	50%
7	60%
8	70%
9	80%
10	90-100%

Acidity: Sugar ratio was evaluated by taste .The more dominant the flavour the higher the number used to describe it. (Table 4.6)

Table 4.6 Acidity :Sugar ratio descriptor

Acidity: Sugar ratio	Description
1\1	The sourness and sweetness are on the same level
1\2	The sweetness is slightly stronger than the sourness
1\3	The sweetness is stronger than the sourness
1\4	The sweetness is much stronger than the sourness
2\1	The sourness is slightly stronger than sweetens
3\1	The sourness is stronger than sweetness
4\1	The sourness is much stronger than sweetness

Sample : the number of fruits per accession was 5 .In some cases there was no fruit at all on the tree or very small amount and therefore the sample was scored lower than 5.The fruits were harvested from all parts of the tree and from all the 3 trees.

Firmness (1-9): evaluated by tasting the apples. Firmness is usually measured by a penetrometer and describes with kg/cm^2 units. However due to time constraint firmness was evaluated by tasting the fruits.

Table 4.7 Firmness scale descriptor

Scale	Description
1	Very soft
2	Soft
3	Slightly soft
4	Preferably for eating (soft)
5	X
6	Preferably for eating (Hard)
7	Slightly Hard
8	Hard
9	Very Hard

X = Intermediate score

Taste (1-5): was evaluated based on Eufrin taste descriptor (Eufrin, 2011) and presented on table 2.9

Table 4.8. Taste scale descriptor

Scale	Taste
1	Extremely poor
2	Poor
3	Intermediate
4	Good
5	Excellent

Ripeness level (1-9): was evaluated by taste, colour of seeds and knocking sounds. (Table 4.9)

Table 4.9. Ripeness scale descriptor

Ripeness	Fruit ripeness description
1	Extremely hard with strong astringency taste
2	Hard for eating with astringency taste
3	Slightly hard for eating
4	Good ripeness level for eating, slightly hard.
5	Good ripeness level for eating
6	Slightly soft for eating
7	Some parts of the fruit are soft
8	Large part of the fruit is rotten
9	the entire fruit is Rotten

Skin (1-9): width of the skin evaluated by tasting the fruit and the appearance.

Table 4.10. Skin scale descriptor

Scale	Skin description
1	Very thin skin
2	X
3	Thin skin
4	X
5	Medium size of skin
6	X
7	Thin skin
8	X
9	Very thick skin

X = Intermediate score

In addition to the evaluation, pictures were taken for almost all the accessions (ornamental varieties excluded) in order to document the fruit appearance (shape size and colour) and the inner part of the fruits. The seed colour and the general appearance of the inner part were recorded as well.

All pictures were taken at the same background and indicate the size and colour of the fruits.

Figure 4.4.Fruit photo. Groninger Kroon (Accession number 8 from the CGN collection)

Remarks – Additional information was written in the protocol in order to indicate exceptional phenomenon (biennial behaviour, leaf greenness - indication for nitrogen use efficiency and unique appearance which can indicate diseases).

Disease resistance

In September 2011, 202 accessions of the CGN collection were evaluated for disease resistance. Scab powdery mildew and canker were scored for each accession. The orchard in Randwijk is managed in a conventional way which means that apple scab and powdery mildew are treated by chemical spraying. Canker is treated by removal of infected parts and in some case the whole tree was removed. Scab, powdery mildew and canker were chosen for observation because of their predominance in Dutch apples orchards as described before.

The evaluation was made based on the methodology developed by Lateur and the guidance of Applied Plant Research (PPO) staff (Lateur, 2010; Meijer and Anbergen, pers. comm., 2011).

Powdery mildew: (0-9) the scores are based on visible symptoms on leaves, with 0 being “no symptom at all” and 9 “all tree’s leaves presenting the symptom”. The scores were given based on Lateur & Popular (1996) and are shown in table 4.11.

Table 4.11 Global assessment scale for evaluation of powdery mildew (*Podosphaera leucotricha*) on apple leaves, top shoots and flower clusters(Lateur ,1999)

Scale	Field observations
0	No visible macroscopic symptoms
1	Very Few leaves with secondary infection (0-5%)
2	Secondary infections on leaves immediately apparent, infected leaves thinly scattered over the tree (5-25%)no primary infection
3	Same as 2 but very few primary infections are visible
4	X
5	Widespread secondary infection over the tree , majority of leaves with secondary infections, few twigs or flower clusters with primary infection
6	X
7	Heavy infection, about half of the shoots have primary infections
8	X
9	Extremely heavy infection, nearly all twigs have primary infection

X = Intermediate rating
Primary infection indicated more severe infection which highly influences the tree productivity and growth.
Secondary infection shown as moderate symptoms.

Scab: (0-9) score ranking was based on the leaves and fruits symptoms, 0 standing for “no symptoms at all” and 9 indicating “all tree’s leaves presenting the symptom”. The scores were given based on Lateur & Popular, 1996, evaluation method and presented on table 4.12.

Figure 4.5. Scab symptoms on the leaves.

Table 4.12. Global assessment scale for scab infection (*Venturia inaequalis)* on leaves and fruits (Lateur&Populer,1996)

Scale	Field observations
0	No visible symptom
1	A few small scab spots are detectible on close scrutiny of the tree
2	X
3	Scab immediately apparent, with lesions very thinly scattered over the tree
4	X
5	infection widespread over the tree ,majority of leaves with at least one lesion
6	X
7	heavy infection; multiple lesions or more large surfaces covered by scab on most leaves
8	X
9	Maximum infection; leaves black with scab

X=Intermediate rating

Canker: The scores were given according to the number of symptoms per tree (0 symptoms = 0, 1 symptom = 1, 2 symptoms = 2 etc.). The final score for canker susceptibility and evolution per accession was made by the average symptoms per tree.

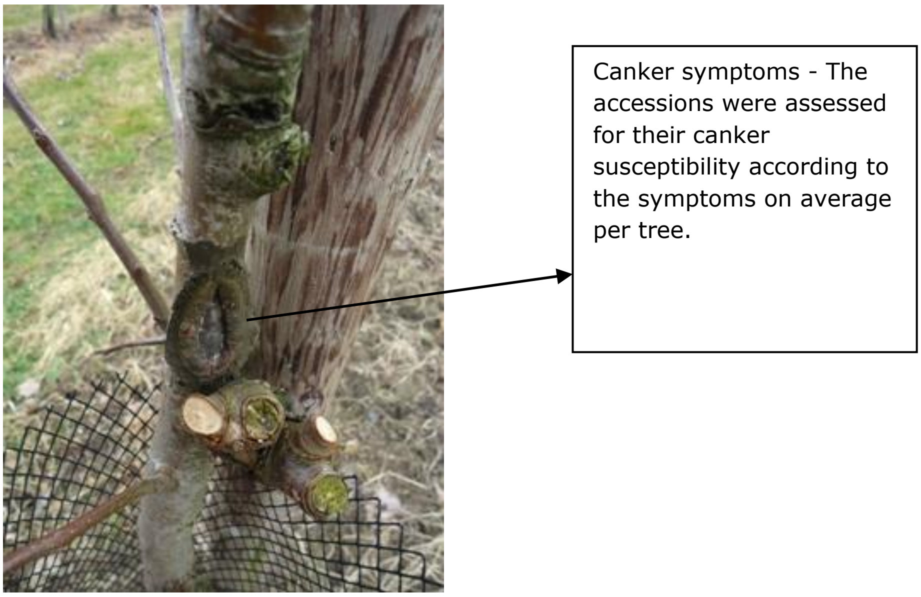


Figure 4.6.Canker Symptom

Tree architecture

In fall 2011, 202 accessions from the CGN collection, 24 accessions from Noordelijke Pomologische Vereniging collection and 21 accessions from Pomologische Vereniging Noord-Holland collection were scored for architectural traits. The traits were chosen according to the interviews and the importance for organic apple growers (briefly described on 3.1 results). The ranking system was developed in collaboration with the PPO guidelines and was based on interviews and literature study completed for the tree ideotype conception. For organic agriculture the best ranking is not necessarily 9 as justified in the tree ideotype description.

The methodology used to describe tree architecture was only partly inspired by Eufrin (Eufrin, 2011). The common classification of tree architectural type is divided into four groups according to tree growth, the distribution of the branches and the fruit position (Lespinasse, 1977). However, according to this classification assessment should take place when the trees are 10 years old according to Upov (International Union for the Protection of New Varieties of Plants). Furthermore, this methodology was not reflecting the interest of organic growers, breeders and researchers in the Netherlands who were curious about a more detailed description of the different architectural traits.

New shoots Average growth (cm) – The average size of the new shoots was estimated by observations of the new shoots grown during the past year (According to figure 2.4) presented in table 4.13.

Table 4.13.New shoots Average growth

Scale	Average growth (cm)
1	<10
2	10
3	15-20
4	20-25
5	25-30
6	30-35
7	35-40
8	>40

New shoots regrowth (1-9): The number of new shoots after pruning last year was counted. According to the pruning strategy in Randwijk, new shoots grow in the space left between branches in the top centre and in the bottom centre.

Table 4.14..New shoot regrowth scale descriptor

Scale	New shoots indication
1	No Shoots
2	X
3	Low amount
4	X
5	Moderate amount
6	X
7	High amount
8	X
9	Extremely high

X = intermediate scale

- The preferably scales for organic growers are between 6-8

'*Bold Branches' (1-9):* The number of the buds and the shoots grow on the side branches were estimated and scored. A score = 1 referred to "bold branch" and a 9 designated a branch with high buds and shoot densities.

Table 4.15. 'Bold Branches' Scale descriptor

Scale	Branch description
1	The branches are completely bold
2	X
3	Small amount of buds and spurs on the branches
4	X
5	Moderate density of spurs and buds on the branches
6	X
7	High density of spurs and buds on the branches
8	X
9	Extremely high density of spurs and buds on the branches

X = Intermediate scale

- The preferably scales for organic growers are between 5 to 7.

Stem Diameter (mm): The trunk diameter was measured 5 cm above the grafting connection, indicating another perspective of vigorous behaviour.

Table.4.16.Stem Diameter scales

Scale	Stem diameter (mm)
1	20-25
2	25-30
3	30-35
4	35-40
5	40-45
6	45-50
7	50-55

Speed of growth (1-9): The tree vigour was reflected in this parameter. The growth of the main trunk, the size of branches, regrowth of new shoots and their sizes as well as the density of foliage were the main factors taken into account for this parameter.

Table 4.17. Speed of growth scales descriptor (Eurfrin, 2011**)**

Scale	Tree growth description
1	: extremely weak
2	X
3	: weak
4	X
5	: intermediate ('Smoothee')
6	X
7	: vigorous
8	X
9	: extremely vigorous

X = intermediate scale

- The preferably scales for organic growers are between 5-6

Branches' Angles (1-9): The accession's branches were observed and scored based on the tree ideotype description (M&M 2.1, Figure 2.1).The flexibility of the branches was also taken into account.

Table 4.18. Branches' angles scales descriptor

Scale	Angle between the branches and the main trunk	Flexibility of the branches
1	30°	Low
2	30°	High
3	30°-60°	Low
4	30°-60°	High
5	X	X
6	60°-90°	Low
7	60°-90	High
8	90°-120	Low
9	90°-120	High

X = intermediate scale

- The preferably scales for organic growers are between 7-9

General Architectural score (1-9): The score was given based on all the parameters shown above. Additional parameters such as ratio between the width of the branches and the main trunk (1:2 is an optimal ratio), branch distribution (symmetric or asymmetric) were also taken in consideration.

Table 4.19. General Architecture score descriptor

Score	Description
1	All architecture scores out of the preferably range (difference of at least 2 ranking points) according to the organic scale[1]. Poor score for the additional remarks[2].
2	All the architecture scores out of the preferably range (difference of at least 1 ranking point) according to the organic scale. Poor score for the additional remarks.
3	Most architecture scores out for the preferably range (difference of at least 1-2 ranking point) according to the organic scale. Poor score for the additional remarks.
4	X
5	Few architecture scores on the preferably range for the organic scale (difference of at least 1 ranking point). Medium performances for the additional remarks.
6	X
7	Some of the architecture scores on the preferably range for the organic scale. Good score for the additional remarks.
8	Almost all architecture scores on the preferably range for the organic scale. Good score for the additional remarks
9	All architecture scores on the scale. Great score for the additional remarks

X = intermediate scale

[1] = The scales that indicated as preferable for organic agriculture on the previous tables.

[2] = Additional remarks refers to symmetric distribution of the branches , the ratio between the main trunk and branches diameters.

- The preferably scales for organic growers are between 7-9

Tree architecture was documented on pictures as well, which can indicate general branching and growth habit.

Figure 4.7.General appearance of tree architecture. (Groninger Peppeling, accession 5 at the CGN collection).

202 accessions in total were observed from the CGN collection in Randwijk. All the accessions were scored for performance for all architecture and disease susceptibility traits. Fruit quality traits were not scored for some accessions because of low yield production and over ripeness level. The ornamental accessions (21) were excluded from fruit quality measurements. An overall view of the observations is presented on the table 4.20 below.

Table 4.20. Observed accession per fruit quality traits in the CGN collection. (2011).

Trait	Number of observed accession	Missing Values
Yield	202	0
Fruit drop%	202	0
Shape	136	66
Fruit diameter size	136	66
Over colour	136	66
Over colour%	136	66
Base Colour	136	66
Brix	129	73
Firmness	129	73
Ripeness level	129	73
Acidity: Sugar ratio	127	75
Taste	127	75
Skin	127	75

*Missing values due to no yield, over ripeness and 21 ornamental accessions that were excluded.

4.1.3. Statistical analysis

The statistical analyses were undertaken with Genestat© 14th edition.

Multivariate analysis

A Principal Component Analysis (PCA) was performed to analyse the information contained into the multivariate data. In order to reduce the variance between the different variables, all the data were standardized to fit the same scale. A correlation matrix was constructed to indicate traits that have similarities and might be (negatively) correlated (Eriksson, 2001). The results were visualized in a biplot graph. The accessions were labelled according to their origin and year of cultivation in order to obtain clusters based on those parameters. In addition major traits were subjected to descriptive statistics. Traits which seemed relatively correlated according to their axes on the PCA analysis were further examined with a linear regression.

Origin and year of cultivation comparison

A comparison based on the country of origin was performed to assess the existence of suitable traits for organic management among the Dutch cultivars. In addition, the accessions were divided into two groups according to the year of release to investigate potential differences between modern cultivars originating from breeding programs focusing on yield production and old cultivars originating from breeding programs emphasizing fruit quality (before 1940). Fruit quality, architectural traits, yield and disease susceptibility were tested. The data were analysed with two sample T-test, one variate with group factor due to the unequal number of observations between the groups.

Architecture comparison within the same accessions evaluated in different collections was conducted by Anova, unbalanced design due to the unequal number of observations which creates unequal variance between the groups, considering interaction between collection and accession name. All architectural traits were examined.

Additional data sets analysis

To give wider and more in-depth comparisons, additional disease susceptibility analyses were carried out, by combining data collected at the CGN in 1999 and 2007 (supplied by Bertus Meijer, Curator of the CGN collection) and by Bloomers, 1983. All data sets were standardized to fit the same scale to reduce large differences of variance resulting from different measurement methods. An Anova (unbalanced design) was performed to check for differences between years, cultivars and interactions.

4.2. Results

4.2.1 General distribution of the measured traits and variation within the CGN collection

The variation within the CGN collection

Comparison between old cultivars (bred before 1940) and new cultivars (bred after 1940)

The CGN collection contains accessions that were cultivated during the last 4 centuries, showing a great diversity between the agronomic traits which are highly important for the organic growers. The years of cultivation reflecting the trend of the breeding and the cultivation at the time of cultivation and being in use. The objective of apple breeding has changed after the Second World War form small scales farms to a more productive farm system. The next graphs show the great diversity in the fruit quality and production, architecture and disease susceptibility traits referring to the year of cultivation or the year that the variety was bred. Accessions without available information about the cultivation year are marked as "Most likely before 1940" out of the assumption that cultivars that was bred after 1940 was documented and registered as a new variety. However, it is possible that some of the accessions were bred around 1940 and therefore these accessions are regarded as "Most likely before 1940" to avoid any misassumptions.

Comparison between cultivars from different origin

An important cultural aspect for apple growers is to find local varieties which can be grown in organic condition or can be used as potential parents for future organic breeding programs. Therefore, another comparison between cultivars from worldwide origin and cultivar from the Netherlands was carried out. Accessions without any information about their origin regarded as 'Most Likely Netherlands'.

Although there is uncertainty of 100 accessions about their origin, it seems that these accessions have an integral part of the Dutch apple tradition due to the reason that those accessions maintained at the pomological associations' collection and at the CGN collection.

Comparison summary – year of cultivation

In order to examine significant differences within the different origin and year groups with two sample T-test was carried out. The tables, 4.2.1 and 4.2.4, contain the most important traits that influence on each category and excluded non- linear traits (appearance traits for instance). All traits with a significant difference are included. In order to compare cultivars that were bred or first discovered after world war, with the focus on high yield, to cultivars that has been in use before for their important agronomic traits of architecture, fruit quality and disease resistance, the accessions were divided into two groups according to the data available on the CGN website, 2012. The year of cultivation or first being in use after breeding of 61 accessions out of 202 is known. 46 cultivars were bred before 1940 and 16 after 1940 and 141 accessions are not known (most likely before 1940). However it is more than likely that those accessions were bred before 1940. Because of the uncertainty, those accessions were excluded from the statistical analysis. The compared traits in table 4.2.1 were not significantly different between the two categories (p value > 0.05) except for the yield production (p value = 0.001). Neither disease susceptibility or tree architecture traits differ significantly between those groups. The general mean score for yield production for cultivar bred before 1940 was 1.98 and after 1940 was 3.55, with least significant difference score of 0.92 that indicates remarkable differences between the two groups. However it is highly important to regard to the differences of ripeness time of the fruits between the cultivars. It is possible that some really early varieties (ripeness time in June for instance) were excluded due to the time of the observations (mid-September). However, the possibility that these early varieties did not show any tracks of fruit on the ground is low. Therefore the conclusions that can be made out of the yield comparison are limited and give a slight indication about the differences between cultivars that bred before and after 1940.

Comparison summary – Country of origin

Out of 202 accessions, 102 accessions have an available information about their origin (CGN, 2011). 58 bred in the Netherlands, 44 worldwide and 100 accessions are unknown (Most likely to be Dutch). Because of the uncertainty these accessions were excluded from the statistical analysis.

The categories that shown significant difference between Dutch accessions and worldwide origin accessions (results shown in table 4.2.2) were fruit quality and production. Architecture traits and diseases susceptibility were not significantly different between the two origin categories (P value> 0.05). The traits on fruit quality that show clear differences were brix level and yield production. Brix level was significant higher for Dutch accessions (Mean =14.72) than worldwide accessions (mean=13.75) with *p value = 0.04* and least significant score (L.S.D) of 0.93. Dutch accessions shows higher yield production (mean =2.47) than worldwide accession (mean=1.73) with p value=0.03 and least significant score of 0.68. However this comparison is limited due to the reason that mentioned on the years of cultivation comparison above.

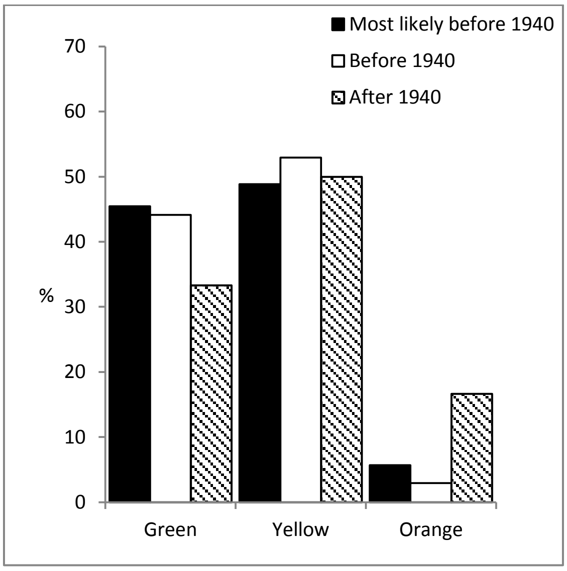
Fruit data (Quality, Production and Appearance)

The next figures are presenting the diversity of apple fruit quality that was measured. Subjective measurements of traits that based on taste and ripeness level (taste, acidity sugar ratio, firmness, ripeness and skin) were excluded from this report. The effects of narrowing down the biodiversity can clearly be shown on figure 4.2.1 (base colour), 4.2.2 (over colour) and 4.2.3 a, b (shape). These traits are indicating the appearance of the fruits.

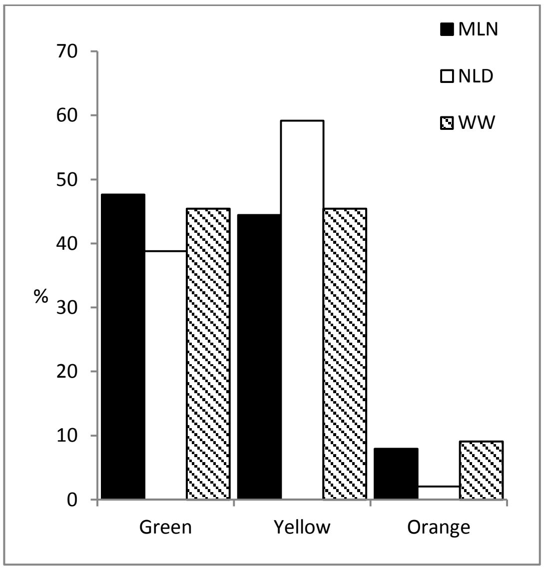
The base colour distribution according to the year show slightly higher percentage for the yellow colour while on the distribution according to the origin only the Dutch accession shows the same trend.

For both comparisons it is clear that orange base colour was discriminate while yellow and green distribution is almost equal. The main phenomenon that can be seen is the high percentage of yellow colour compared to green colour within the Dutch accessions and the accessions that were bred after 1940.

a) Distribution referring to the cultivation year (%)



c) Distribution referring to the origin (%)



b) *Distribution referring to the cultivation year (observations)*

Base Colour	Most likely before 1940	Before 1940	After 1940
Green	40	15	4
Orange	5	1	2
Yellow	43	18	6
Total	88	34	12

d) Distribution referring to the origin (observations).

Base Colour	MLN	NLD	WW
Green	30	19	10
Orange	5	1	2
Yellow	28	29	10
Total	63	49	22

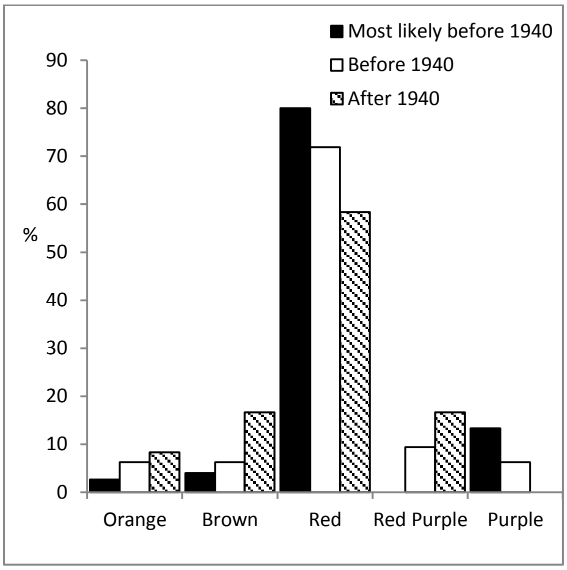
MLN=most likely Netherlands,

NLD=The Netherlands, WW=worldwide

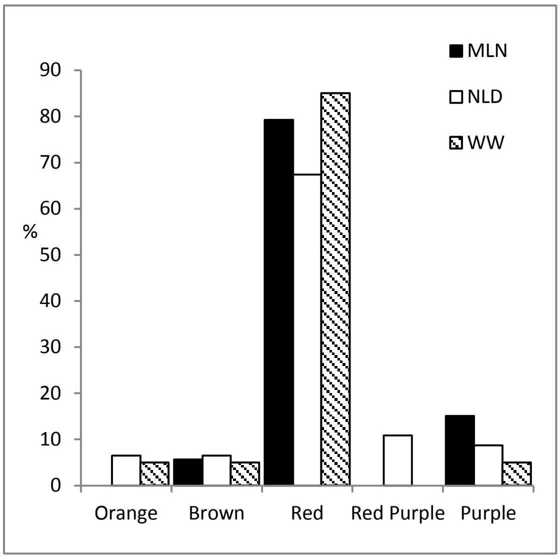
Figure 4.2.1 Base colour distributions referring to year of cultivation and the origin. For each category the results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

The over colour distribution (figure 4.2.2) is clearly in the favour of red colour while all the other colours were abandoned for all the categories. However, the varieties that were bred before 1940 show a higher percentage of red colour in comparison with varieties that were bred after 1940. 80% of the accessions that were most likely bred before 1940 and 71.87% that bred before 1940 found with red colour, while the distribution for accessions that were bred after 1940 is more equally speared but with a big preference for red colour. For the worldwide accessions 85% have a red colour while the Dutch accession and the most likely Dutch accessions show more moderate distribution.

a) Distribution referring to the cultivation year (%)



c) Distribution referring to the origin (%)



b) *Distribution referring to the cultivation year (Observations)*

Over colour	Most likely before 1940	Before 1940	After 1940
Brown	3	2	2
Orange	2	2	1
Purple	10	2	0
Red	60	23	7
Red Purple	0	3	2
Total	75	32	12

d) Distribution referring to the origin (observations).

Over colour	MLN	NLD	WW
Brown	3	3	1
Orange	0	3	1
Purple	8	4	1
Red	42	31	17
Red Purple	0	5	0
Total	53	46	20

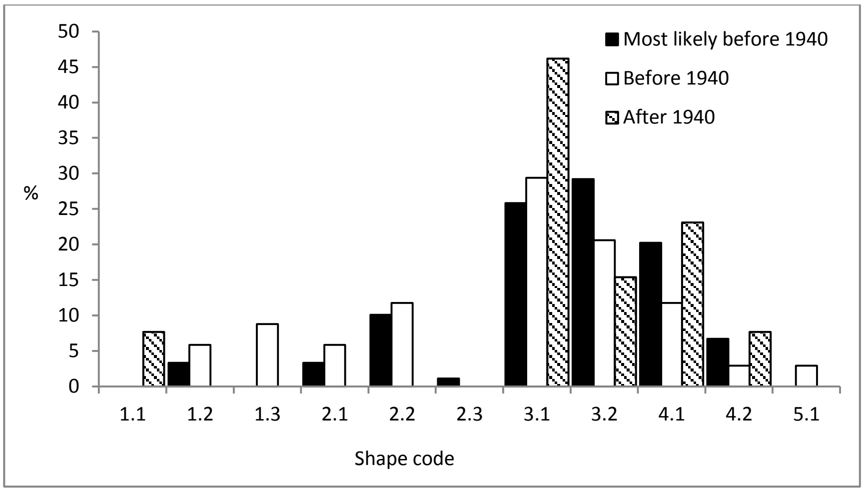
MLN=most likely Netherlands,

NLD=The Netherlands, WW=worldwide

Figure 4.2.2 colour distribution referring to year of cultivation and the origin. For each category the results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations.

The high percentages for fruit shape 3.1 are common for the accessions that were bred after 1940 and bred before 1940. The accessions that were bred most likely before 1940 the distribution of shapes 3.and 3.2 is almost equal, while 4.1 found with a bit lower percentages.

a) Distribution referring to Cultivation year (%)



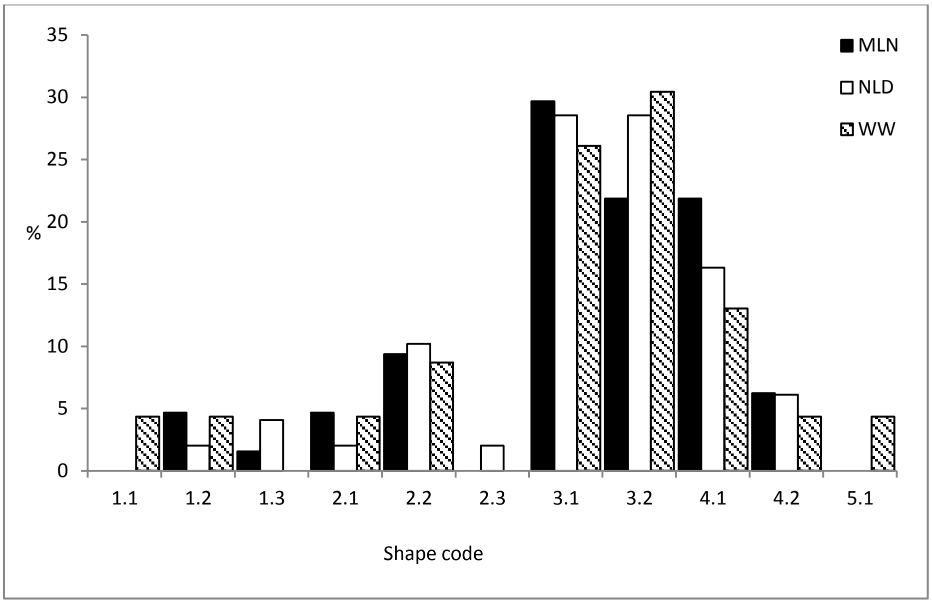
b)Distribution referring to Cultivation year (observations).

Shape code	Most likely before 1940	Before 1940	After 1940
1.1	0	0	1
1.2	3	2	0
1.3	0	3	0
2.1	3	2	0
2.2	9	4	0
2.3	1	0	0
3.1	23	10	6
3.2	26	7	2
4.1	18	4	3
4.2	6	1	1
5.1	0	1	0
Total	89	34	13

Figure .4.2.3a. Fruit Shape distribution referring to year of cultivation. The results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations.(Fruit shape descriptor in appendix I)

For the accessions from worldwide and most likely Netherlands, shape 3.2 shows the highest numbers while for the Dutch accession 3.1 and 3.2 fruit shapes were observed with the same numbers.

a) Distribution referring to the origin (percentage %)



b) *Distribution referring to the origin (observations).*

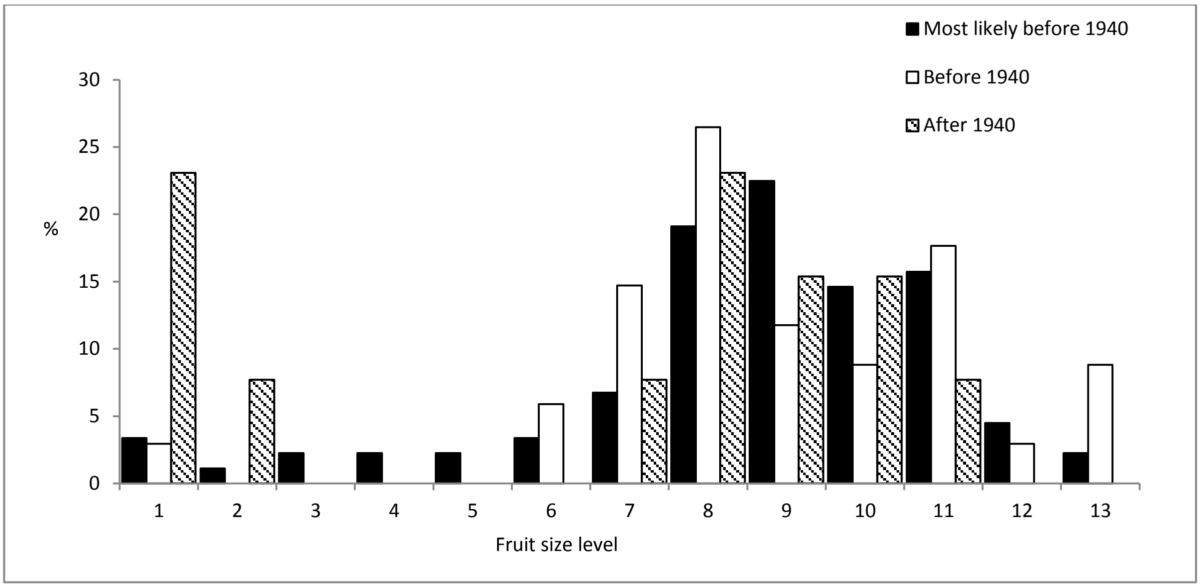
Shape code	MLN	NLD	WW
1.1	0	0	1
1.2	3	1	1
1.3	1	2	0
2.1	3	1	1
2.2	6	5	2
2.3	0	1	0
3.1	19	14	6
3.2	14	14	7
4.1	14	8	3
4.2	4	3	1
5.1	0	0	1
Total	64	49	23

MLN=most likely Netherlands, NLD=The Netherlands, WW=worldwide

Figure.4.2.3b. Fruit Shape distribution referring to origin of cultivation. The results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations.(Fruit shape descriptor in appendix I).

The trend of fruit sizes shows, regarding to all accessions, a preference for fruit diameter of 75-80 mm. However, big fruit sizes (categories 11,12 and 13) are mostly among cultivars who were bred before 1940. While for the accessions that were bred after 1940 it is possible to find small fruit sizes (category 1 and 2.).

a) *Distribution referring to Cultivation year (%)*



b) *Distribution referring to the Cultivation year (observations)*

Fruit size	Most likely before 1940	Before 1940	After 1940
1	3	1	3
2	1	0	1
3	2	0	0
4	2	0	0
5	2	0	0
6	3	2	0
7	6	5	1
8	17	9	3
9	20	4	2
10	13	3	2
11	14	6	1
12	4	1	0
13	2	3	0
Total	89	34	13

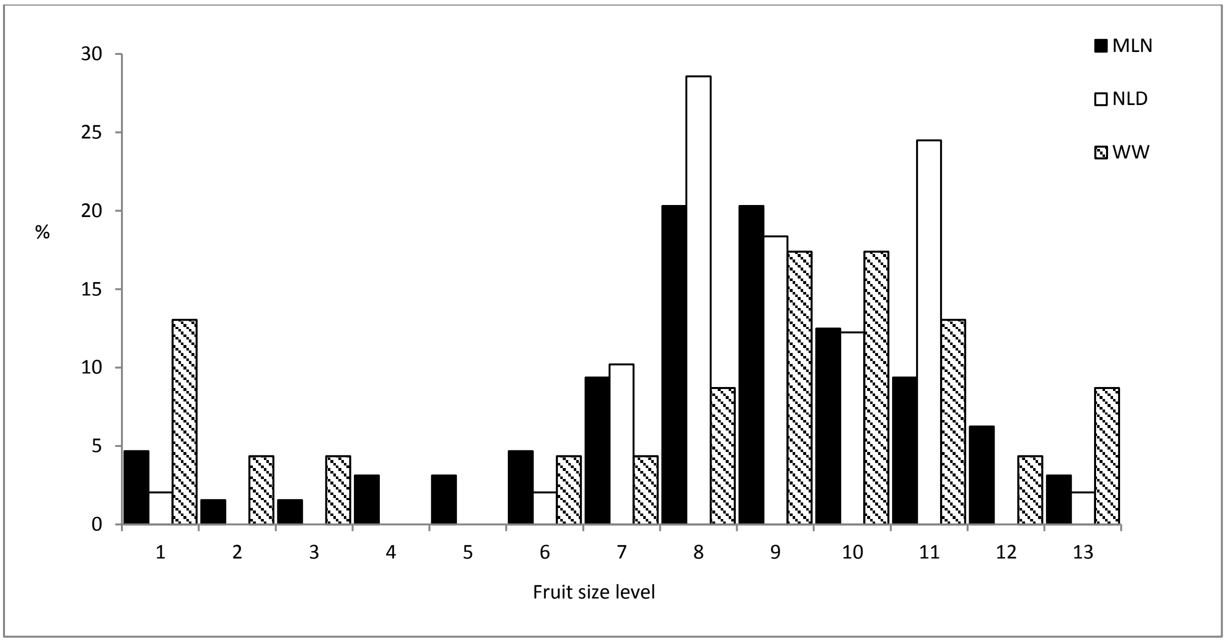
c) *Fruit size level in mm*

Fruit size Level	Fruit size Diameter(Mm)
1	<45
2	45-50
3	50-55
4	55-60
5	60-65
6	65-70
7	70-75
8	75-80
9	80-85
10	85-90
11	90-95
12	95-100
13	100-105

Figure 4.2.4a. *Fruit diameter sizes distribution referring to the year of cultivation. The results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations.*

Fruit sizes of 75-80mm diameter were found in higher percentages for Dutch accessions. For the most likely Netherlands, the observation of accessions with fruit sizes level of 8 and 9 is equal, while for the worldwide accessions bigger level sizes are preferable (9,10) and the distribution is more moderate than in the other two groups. A large group of accessions with size level of 1was found within the worldwide accessions.

a) Distribution referring to the origin (%)



b) *Distribution referring to the origin (Observations)*

Fruit size	MLN	NLD	WW
1	3	1	3
2	1	0	1
3	1	0	1
4	2	0	0
5	2	0	0
6	3	1	1
7	6	5	1
8	13	14	2
9	13	9	4
10	8	6	4
11	6	12	3
12	4	0	1
13	2	1	2
Total	64	49	23

c) Fruit size level in mm

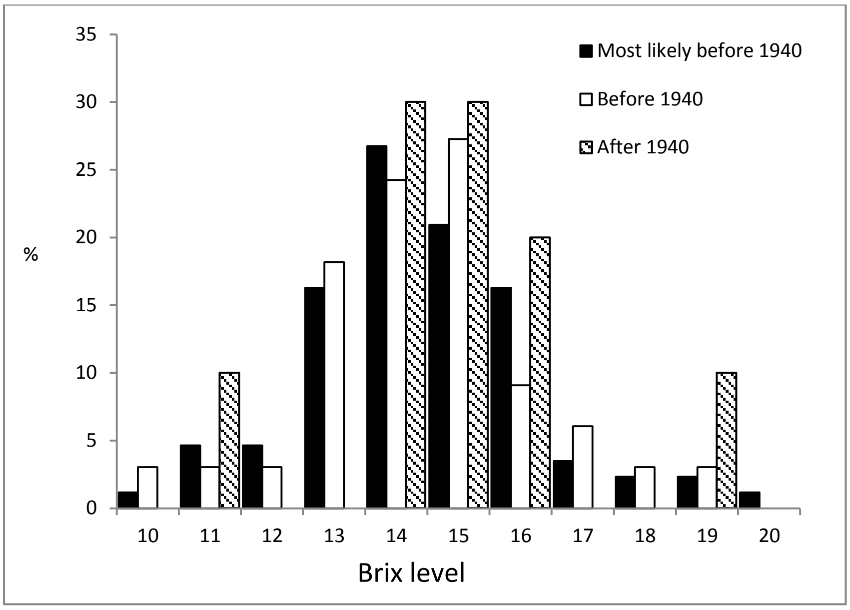
Fruit size Level	Fruit size Diameter(Mm)
1	<45
2	45-50
3	50-55
4	55-60
5	60-65
6	65-70
7	70-75
8	75-80
9	80-85
10	85-90
11	90-95
12	95-100
13	100-105

MLN=most likely Netherlands, NLD=The Netherlands, WW=worldwide

Figure 4.2.4b. *Fruit diameter sizes distribution referring to the origin of cultivation. The results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations.*

Most of the Brix accessions (sugar level %) values vary between 14-15. However, it seems that there is a higher percentage of high sugar content (16 and 19 Brix levels) within the accession that were bred after 1940. The brix level was not significantly different between cultivars bred before and after 1940 (Table 4.2.1).

a) Distribution referring to the cultivation year (%)



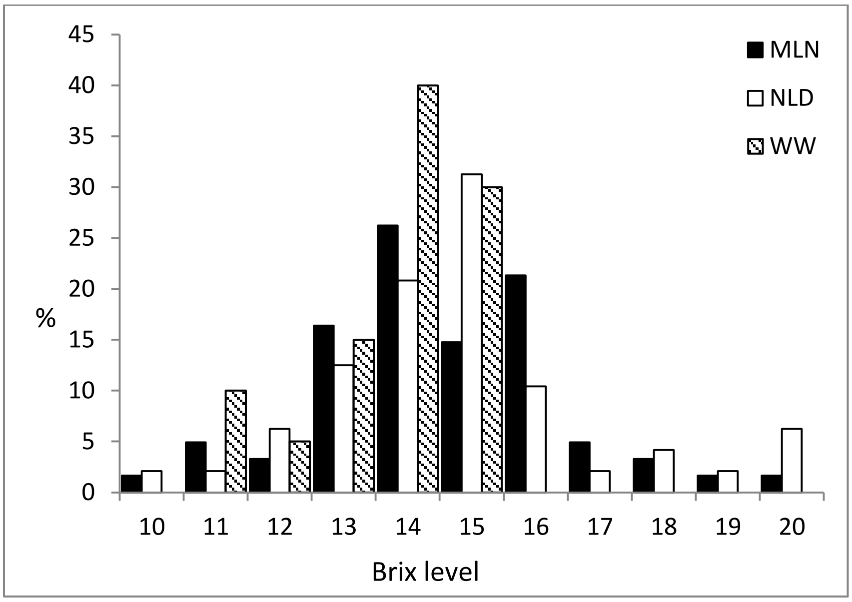
b) Distribution referring to the cultivation year (observations)

Brix (sugar level %)	Most likely before 1940	Before 1940	After 1940
10	1	1	0
11	4	1	1
12	4	1	0
13	14	6	0
14	23	8	3
15	18	9	3
16	14	3	2
17	3	2	0
18	2	1	0
19	2	1	1
20	1	0	0
Total	86	33	10

Figure 4.2.5a *Fruit Brix (sugar level %) distribution referring to year of cultivation. The results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations.*

Most of the accession from worldwide show moderate levels of sugar content (categories 14, 15) while the Dutch and most likely Netherland origins accessions show more moderate distribution and higher Brix levels. The brix level was significantly higher (*p value=0.04)* for the Dutch accessions compare to the worldwide accessions (Table 4.2.2).

a) Distribution referring to the origin (%)



b) *Distribution referring to the origin (Observations)*

Brix (sugar level %)	MLN	NLD	WW
10	1	1	0
11	3	1	2
12	2	3	1
13	10	6	3
14	16	10	8
15	9	15	6
16	13	5	0
17	3	1	0
18	2	2	0
19	1	1	0
20	1	3	0
Total	61	48	20

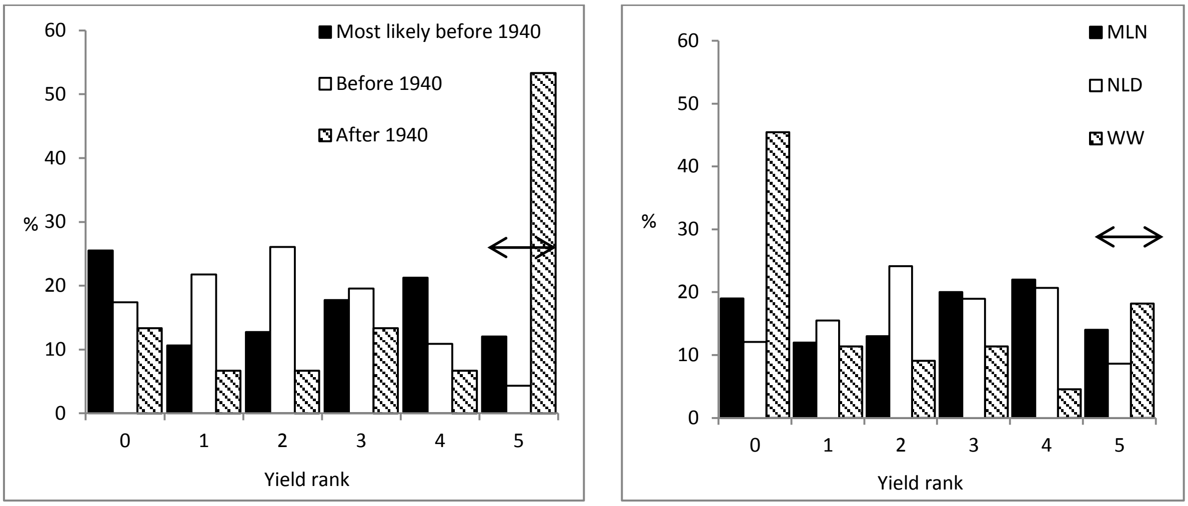
MLN=most likely Netherlands, NLD=The Netherlands, WW=worldwide

Figure 4.2.5b *Fruit Brix (sugar level %) distribution referring to origin of cultivation. The results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations.*

Yield production for cultivars that were bred after 1940, were obviously found in a high percentage within the 5 and highest category of yield level while the other groups present more moderate distribution between the different levels of yield production. For the accession that was cultivated in the Netherlands and most likely in the Netherlands the distribution is moderate. However for the worldwide origin accession, there is a large group that showed no production at all. Yield production was found significantly higher *(p value < 0.01)* for to accessions bred after 1940 compare to accessions bred before 1940 (table 4.2.1). The Dutch accessions had higher yield production than the worldwide accessions *(p value=0.03).*

a) *Distribution referring to the cultivation year (%)*

c) *Distribution referring to the origin (%)*



b) *Distribution referring to the cultivation year (observations)*

Score	Most likely before 1940	Before 1940	After 1940
0	36	8	2
1	15	10	1
2	18	12	1
3	25	9	2
4	30	5	1
5	17	2	8
Total	141	46	15

←→ Indicates the range of the preferably scales for organic growers

d) *Distribution referring to the origin (Observations)*

Score	MLN	NLD	WW
0	19	7	20
1	12	9	5
2	13	14	4
3	20	11	5
4	22	12	2
5	14	5	8
Total	100	58	44

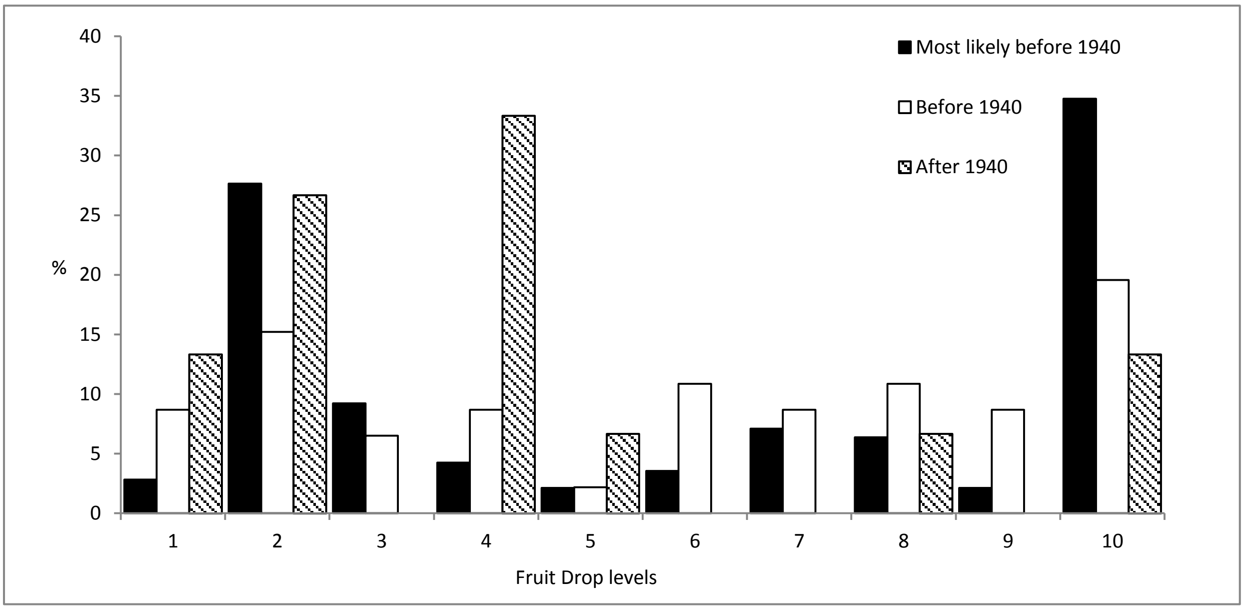
MLN=most likely Netherlands,

NLD=The Netherlands, WW=worldwide

Figure 4.2.6 Yield Production distribution referring to year of cultivation and the origin. For each category the results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

Fruit drop % for the accessions that were bred before or most likely before 1940 were distributed at an equal ratio of percentage except of a large group that was observed in high numbers in categories 10(100% fruit drop) and 2 (10%). Cultivars that were bred after 1940 were distributed equally with the preference for category 2(10%) and 4 (30%).

a) *Distribution referring to the cultivation year (%)*



b) Distribution referring to the cultivation year (observations)

Score	Most likely before 1940	Before 1940	After 1940
1	4	4	2
2	39	7	4
3	13	3	0
4	6	4	5
5	3	1	1
6	5	5	0
7	10	4	0
8	9	5	1
9	3	4	0
10	49	9	2
Total	141	46	15

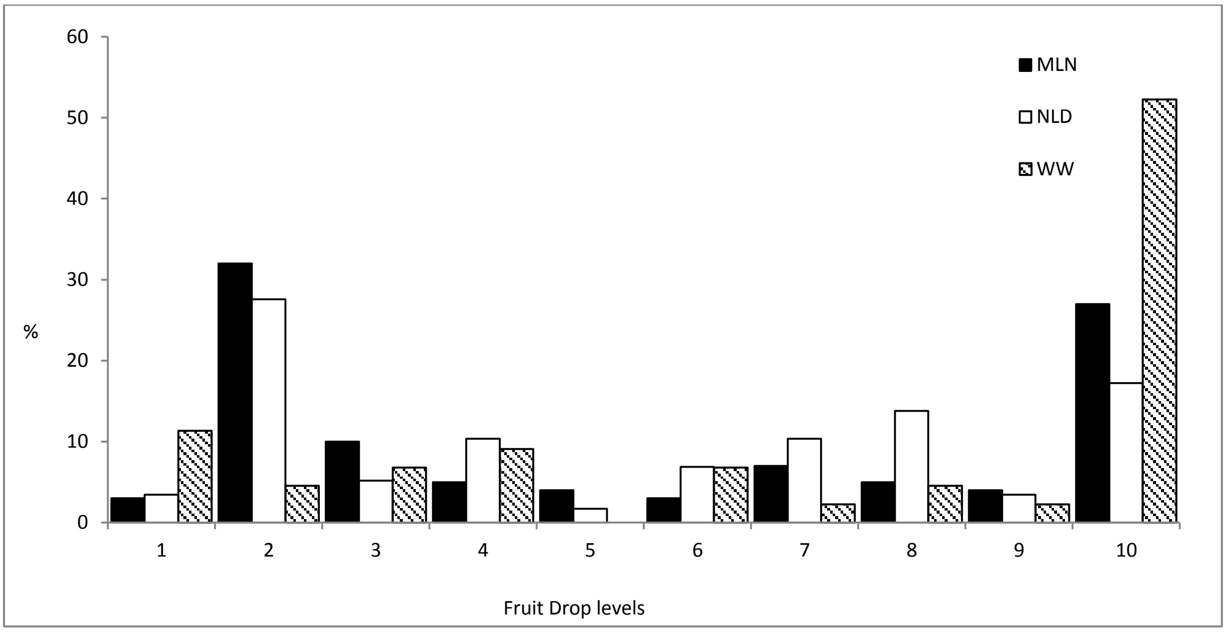
c) Fruit drop scales (%)

Fruit drop categories	Fruit drop %
1	5%
2	10%
3	20%
4	30%
5	40%
6	50%
7	60%
8	70%
9	80%
10	90-100%

4.2.7a. Fruit Drop % distribution referring to the year of cultivation. The results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations.

Accessions from the Netherlands and most likely Netherlands had equal distribution with a preference for groups 2 (10%) and 10(100%) while accession from worldwide were found with high numbers with fruit drops of 100%

a) *Distribution referring to the origin (%)*



b) Distribution referring to the origin (Observations)

Score	MLN	NLD	WW
1	3	2	5
2	32	16	2
3	10	3	3
4	5	6	4
5	4	1	0
6	3	4	3
7	7	6	1
8	5	8	2
9	4	2	1
10	27	10	23
Total	100	58	44

c) Fruit drop scales in percentage

Fruit drop categories	Fruit drop %
1	5%
2	10%
3	20%
4	30%
5	40%
6	50%
7	60%
8	70%
9	80%
10	90-100%

4.2.7b. Fruit Drop % distribution referring to origin of cultivation. The results shown as a percentage out of the total observation within the category and the tables below indicated the actual observations

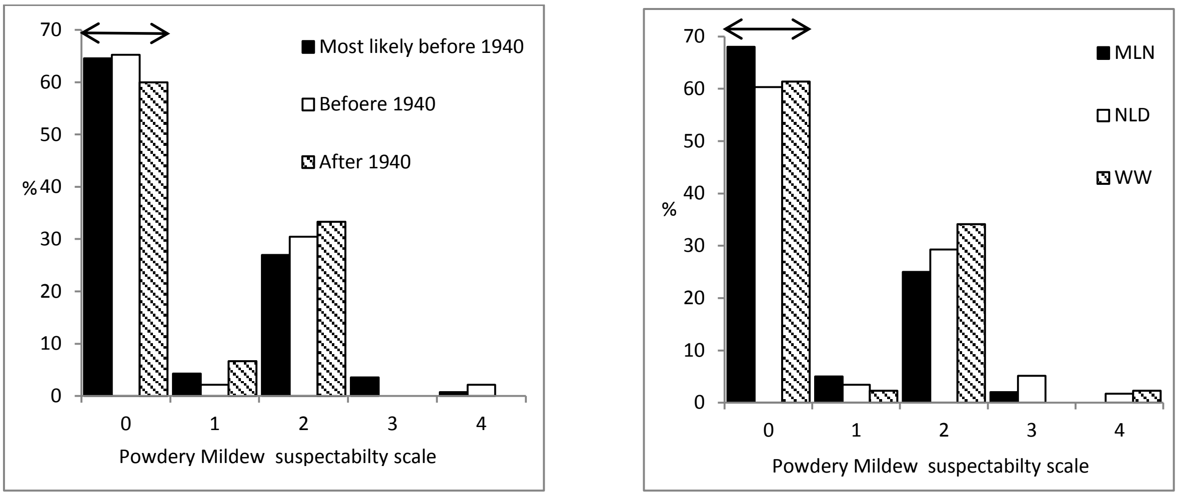
Disease susceptibilities

The symptoms of diseases that were obtained in the CGN collection were slightly shown due to the effect of the pesticides and fungicides that are regularly sprayed. The next figures present the general distribution for disease susceptibilities for the three most damaging apple diseases in the Netherlands. However, few symptoms of these diseases can indicate a susceptible cultivar to those diseases. Canker, on the other hand, is not treated by any chemicals and therefore the symptoms were clearer to obtain.

Powdery Mildew (*Podosphaera leucootrich*) symptoms were not obtain for 60% of the cultivars' accessions bred after 1940. 65.21% of the accessions that were in use before 1940 and 64.53% that most likely bred before 1940 (figure 4.2.8). The accessions of the cultivars that were bred after 1940 were found with the most symptoms (susceptibility scale groups 1 and 2). Most of the accessions, referring to their origin, were found without symptoms (60% and more) and the most unsusceptible group was the most likely Netherlands. Only two accessions were found with a high susceptibility with the score of 4 (1 MLN, 1 NLD) (1 Before 1940 and 1 most likely before 1940). The comparison is made in table 4.2.1 and 4.2.2 shows that there were no significant differences between the groups of origin and the year of cultivation referring to the disease susceptibility.

a*) Distribution referring to the cultivation year (%)*

c) Distribution referring to the origin (%)



b) Distribution referring to the cultivation year

(Observations)

Score	Most likely before 1940	Before 1940	After 1940
0	91	30	9
1	6	1	1
2	38	14	5
3	5	0	0
4	1	1	0
Total	141	46	15

←→ Indicates the range of the preferably scales for organic growers

d) *Distribution referring to the origin*

(Observations)

Score	MLN	NLD	WW
0	68	35	27
1	5	2	1
2	25	17	15
3	2	3	0
4	0	1	1
Total	100	58	44

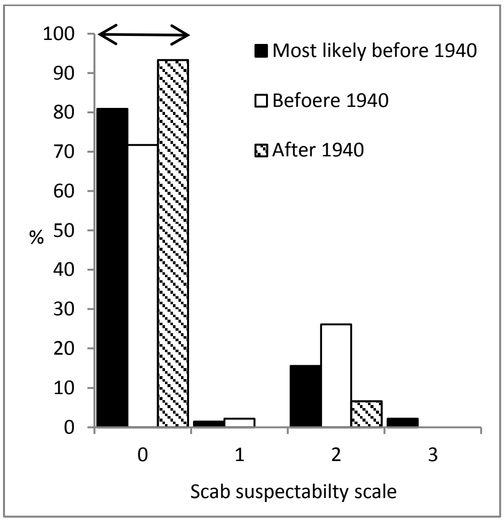
MLN=most likely Netherlands,

NLD=The Netherlands, WW=worldwide

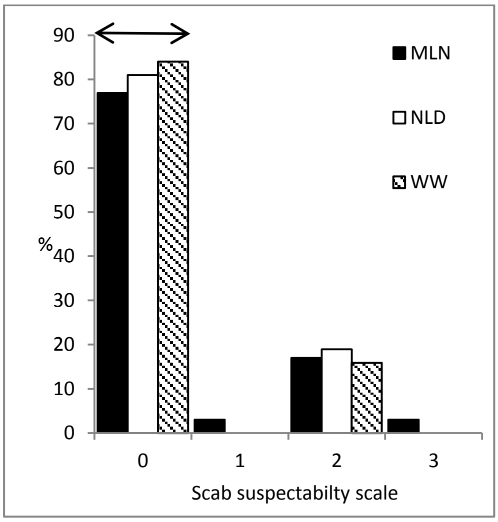
Figure 4.2.8 *Powdery Mildew Susceptibility scales distribution referring to year of cultivation and the origin. For each category the results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.*

93.33% of the accessions that were bred after 1940 were found without any symptoms of Scab (*Venturia inaequalis*) (figure 4.2.9). Accessions that were bred before 1940 or most likely before also showed low susceptibility, with 70% and 80% matching and got the score of 0 (no symptoms). Accessions that are bred before or most likely before 1940 were found in higher percentages within groups 1, 2 and 3 on the scab scale, which obtain higher susceptibility. The only accession that was obtained with relative high symptoms bred most likely before 1940. The worldwide accessions showed the lowest susceptibility with the highest percentage in scale 0 and lower percentages in the other groups. The only accession that was obtained with relative high symptoms was bred most likely in the Netherlands.

a) *Distribution referring to the cultivation year (%)*



c) Distribution referring to the origin (%)



b) Distribution referring to the cultivation year (Observations)

Score	Most likely before 1940	Before 1940	After 1940
0	114	33	14
1	2	1	0
2	22	12	1
3	3	0	0
Total	141	46	15

←→ Indicates the range of the preferably scales for organic growers

d) *Distribution referring to the origin (Observations)*

Score	MLN	NLD	WW
0	77	47	37
1	3	0	0
2	17	11	7
3	3	0	0
Total	100	58	44

MLN=most likely Netherlands,

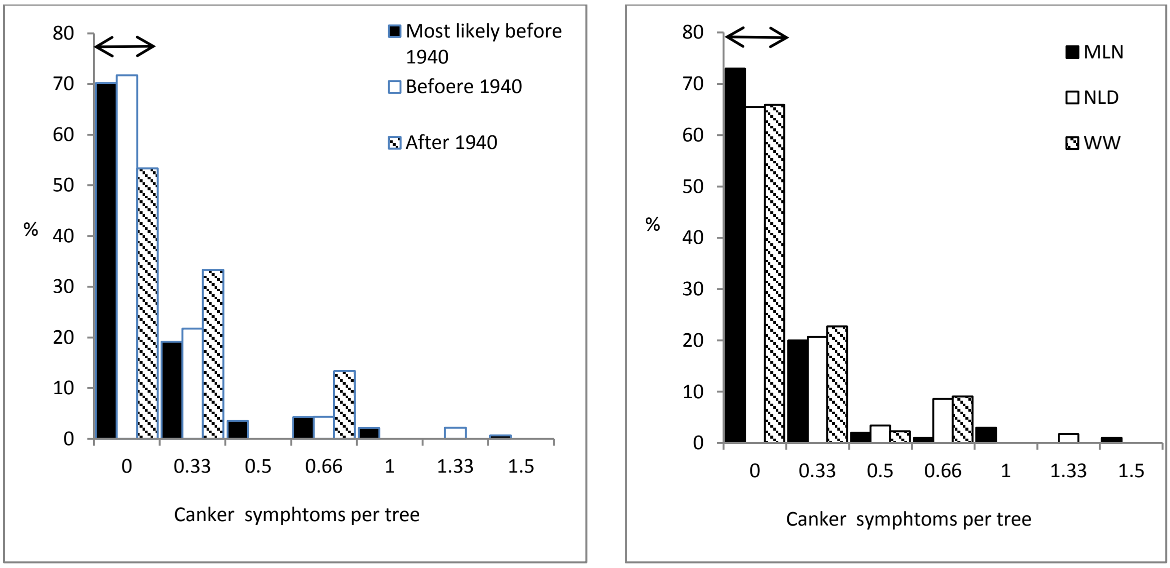
NLD=The Netherlands, WW=worldwide

Figure 4.2.9 Scab *Susceptibility scales distribution referring to year of cultivation and the origin. For each category the results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.*

The Canker (*Neonectria galligena*) results presented here as a number of symptoms per tree (figure 4.2.10). However it is possible that some trees were removed due to a severe canker infection, and therefore for some of the accessions the average could be higher. It is also possible that those trees had to be removed for other reasons and therefore the assumption of removed trees due to canker infection was excluded. Accessions that were bred after 1940 showed higher number of symptoms per tree with the lowest percentages in group 0 (no symptoms) and higher percentages in the groups that indicated symptoms. The worldwide and the Netherlands accessions showed higher percentages than the most likely Netherlands.

a) *Distribution referring to the cultivation year (%)*

c) *Distribution referring to the origin (%)*



b) Distribution referring to the cultivation year

(Observations)

score	Most likely before 1940	Before 1940	After 1940
0	99	33	8
0.333	27	10	5
0.5	5	0	0
0.666	6	2	2
1	3	0	0
1.33	0	1	0
1.5	1	0	0
Total	141	46	15

←→ Indicates the range of the preferably scales for organic growers

d) Distribution referring to the origin

(Observations)

Score	MLN	NLD	WW
0	73	38	29
0.333	20	12	10
0.5	2	2	1
0.666	1	5	4
1	3	0	0
1.33	0	1	0
1.5	1	0	0
Total	100	58	44

MLN=most likely Netherlands,

NLD=The Netherlands, WW=worldwide

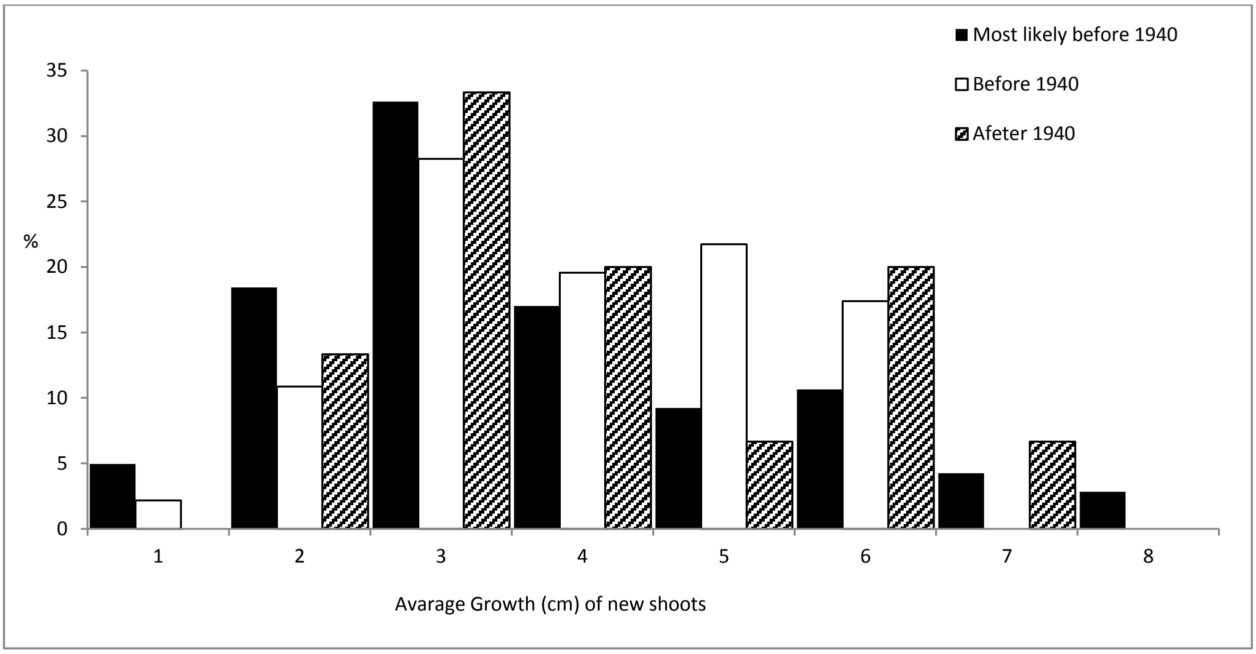
Figure 4.2.10 Canker *Susceptibility scales distribution referring to year of cultivation and the origin. For each category the results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.*

Tree Architecture

The results are presented in the tables 4.2.1 and 4.2.2 do not show a significant difference for all the architectural traits in both the year and the origin comparison. However, the results that are presented in the next figures reveal a great diversity within the CGN collection for the architecture characteristics.

The distribution of the scores for new shoots average growth is spared normal with most accessions on the scale of 3 which indicates 15-20 cm growth per year. However, there is a large group of accessions that were bred after 1940 and scored with 6 which indicates a growth of 30-35 cm per year (Figure 4.2.11a).

a) *Distribution referring to the cultivation year (%)*



b) Distribution referring to the cultivation year (observations)

Scale	Most likely before 1940	Before 1940	after 1940
1	7	1	0
2	26	5	2
3	46	13	5
4	24	9	3
5	13	10	1
6	15	8	3
7	6	0	1
8	4	0	0
Total	141	46	15

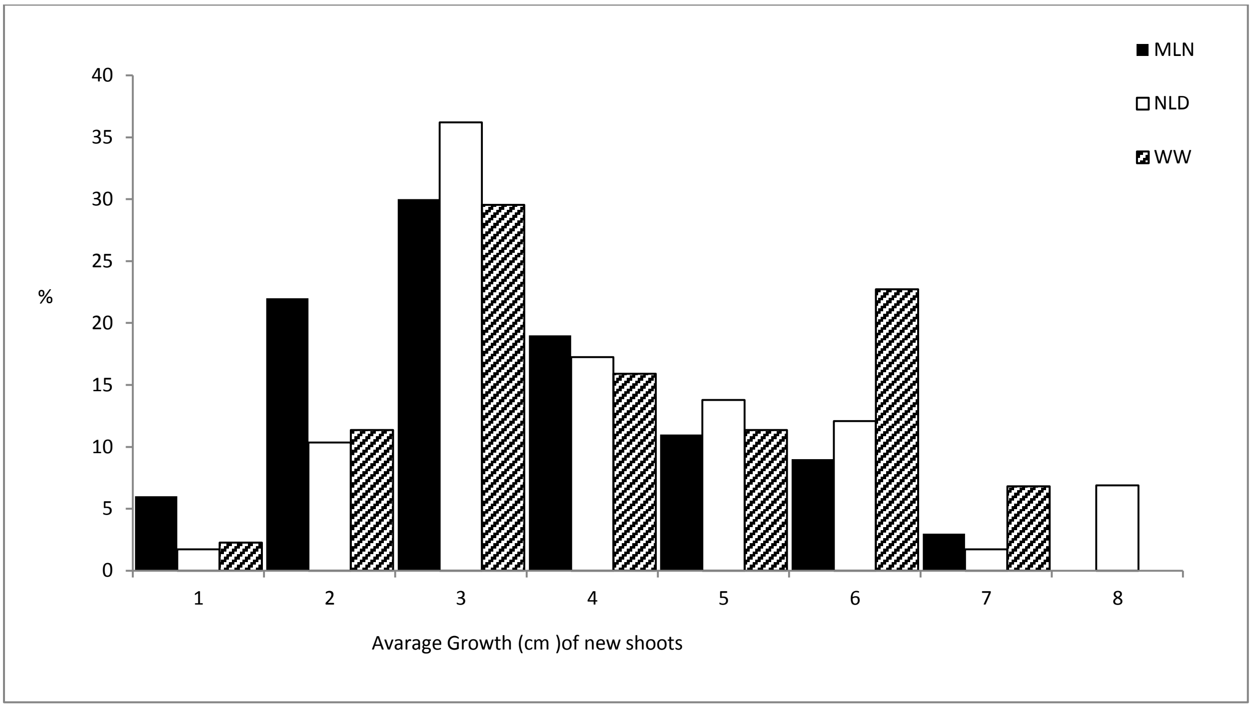
c) Average growth of new shoots scale (cm)

Scale	Average growth (cm)
1	<10
2	10
3	15-20
4	20-25
5	25-30
6	30-35
7	35-40
8	>40

Figure 4.2.11a New shoots average growth scales distribution referring to year of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

The trend of the distribution is the same for the origin as for the year of cultivation with a large exceptional group of worldwide accession that got scored with 6.

a) Distribution referring to the origin (%)



b) Distribution referring to the origin (observations)

Score	MLN	NLD	WW
1	6	1	1
2	22	6	5
3	30	21	13
4	19	10	7
5	11	8	5
6	9	7	10
7	3	1	3
8	0	4	0
Total	100	58	44

c) Average growth of new shoots scale (cm)

Scale	Average growth (cm)
1	<10
2	10
3	15-20
4	20-25
5	25-30
6	30-35
7	35-40
8	>40

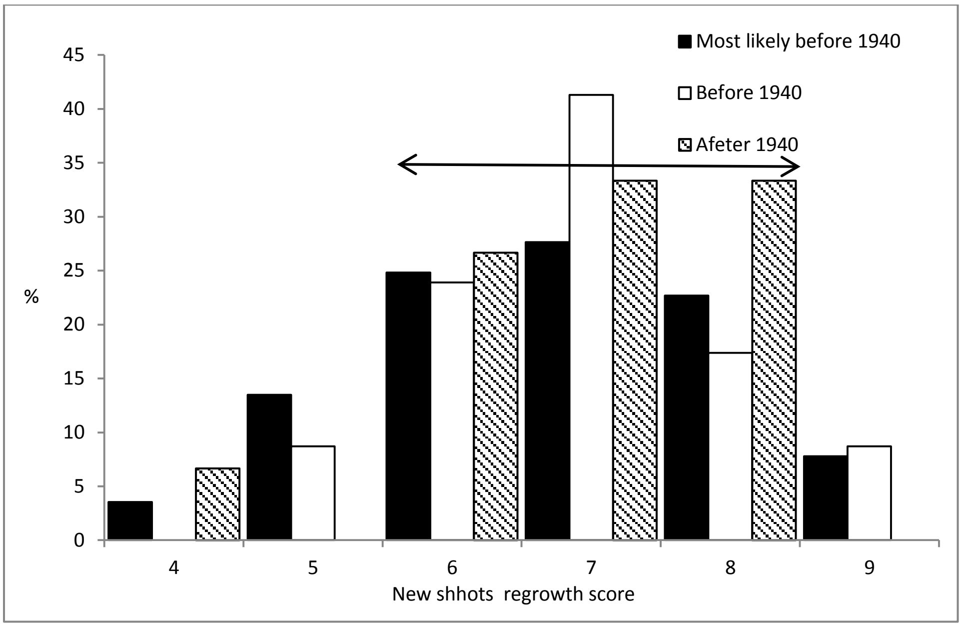
MLN=most likely Netherlands,

NLD=The Netherlands, WW=worldwide

Figure 4.2.11b New shoots average growth scales distribution referring to the origin of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

New shots re-growth indicate the number of new shoots that grew during the last year. Most accessions scored with 7 in all the three categories. The exceptional group are the accessions that were bred after 1940 with high percentages of accessions the got the score of 8 (33.3%). (Figure 4.2.12a).

a) *Distribution referring to the cultivation year (%)*



←→ Indicates the range of the preferably scales for organic growers

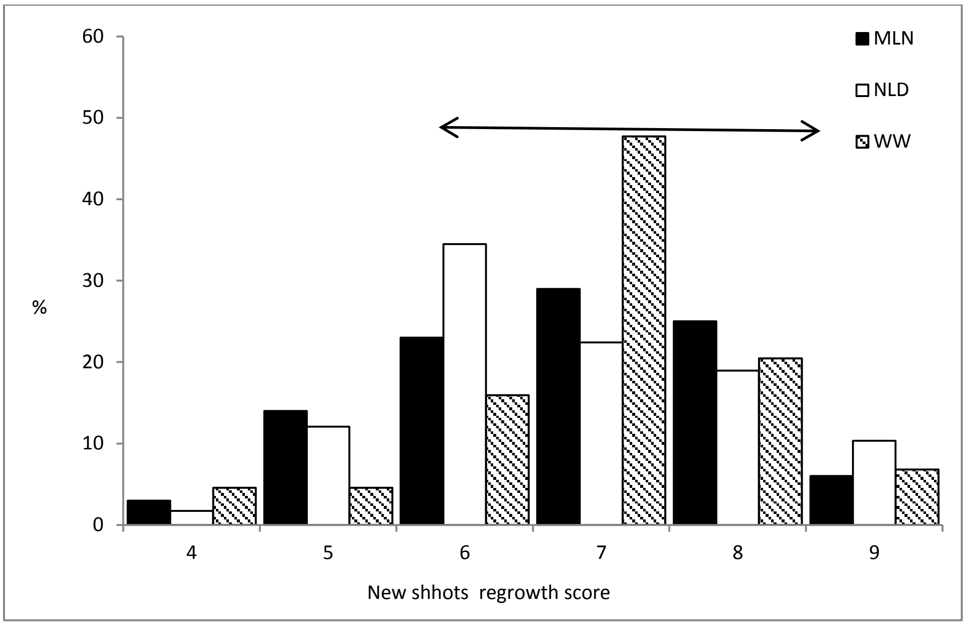
b*) Distribution referring to the cultivation year (Observations)*

Score	Most likely before 1940	Before 1940	After 1940
1	0	0	0
2	0	0	0
3	0	0	0
4	5	0	1
5	19	4	0
6	35	11	4
7	39	19	5
8	32	8	5
9	11	4	0
Total	141	46	15

Figure 4.2.12a.New shoots regrowth scales distribution referring to year of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

The accessions distribution referring to origin speared normally. Most Dutch accessions scored with 6 while in the other two groups of origin most accessions got the score of 7.

a) Distribution referring to the origin (%)



←→ Indicates the range of the preferably scales for organic growers

b) Distribution referring to the origin (observations)

Score	MLN	NLD	WW
1	0	0	0
2	0	0	0
3	0	0	0
4	3	1	2
5	14	7	2
6	23	20	7
7	29	13	21
8	25	11	9
9	6	6	3
Total	100	58	44

MLN=most likely Netherlands

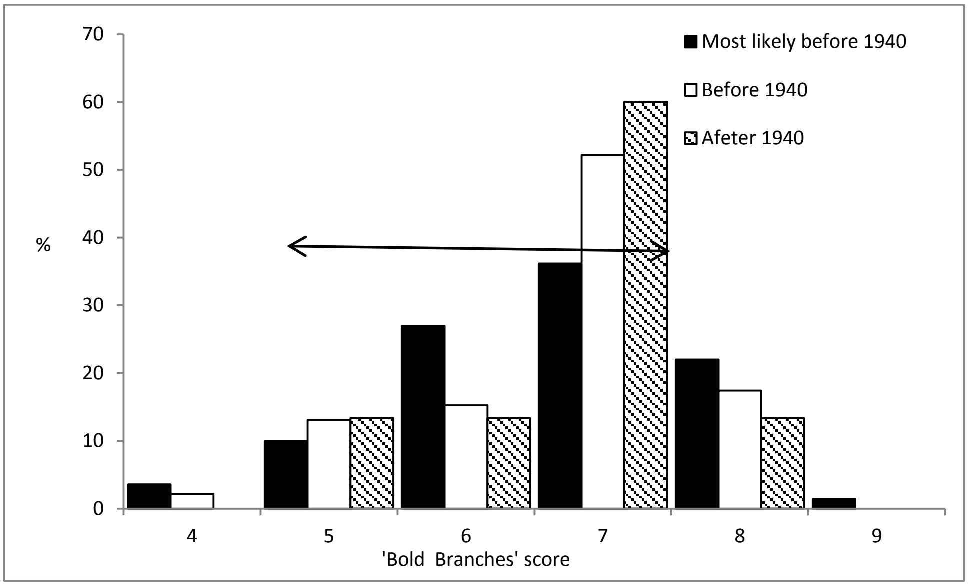
NLD=The Netherlands,

WW=worldwide

Figure 4.2.12b New shoots re-growth scales distribution referring to origin of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

For all year of cultivation categories most accessions got the score of 7 for 'bold shoots' (figure 4.2.13a). 60% of the accessions that were bred after 1940 got the score of 7, 52.17% of the accessions that were bred before got the score of 7 and 36.17% of the accessions that were bred most likely before 1940 scored with 7 and showed more equal distribution compare to the other groups.

a) *Distribution referring to the cultivation year (%)*



←→ Indicates the range of the preferably scales for organic growers

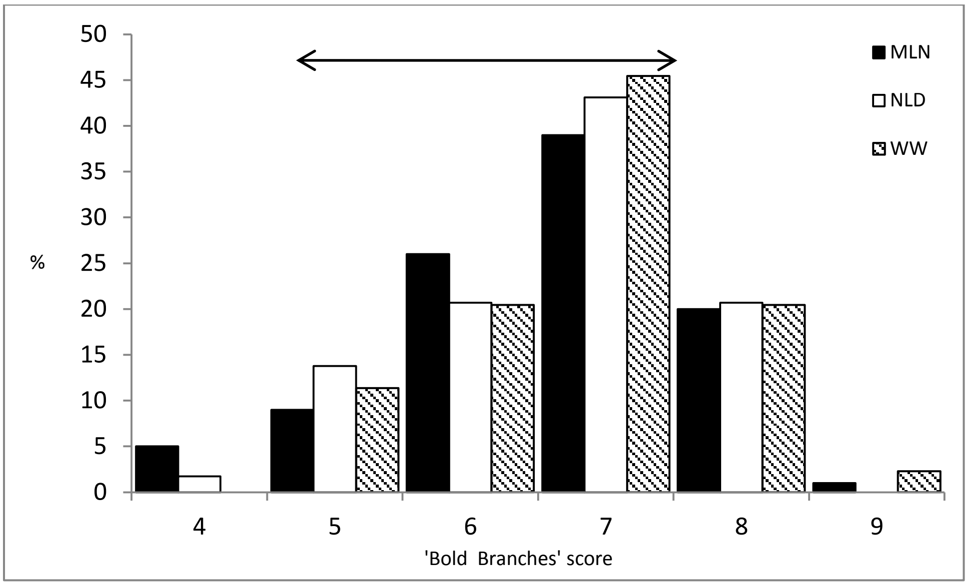
b) *Distribution referring to the cultivation year (observations).*

score	Most likely before 1940	Before 1940	After 1940
4	5	1	0
5	14	6	2
6	38	7	2
7	51	24	9
8	31	8	2
9	2	0	0
Total	141	46	15

Figure 4.2.13a. 'Bold Shoots' scales distribution referring to year of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

For all the categories of origin the most accessions got the score of 7 for bold shoots with a normal distribution.

a) Distribution referring to the origin (%)



←→ Indicates the range of the preferably scales for organic growers

b) Distribution referring to the origin (observations)

Score	MLN	NLD	WW
4	5	1	0
5	9	8	5
6	26	12	9
7	39	25	20
8	20	12	9
9	1	0	1
Total	100	58	44

MLN=most likely Netherlands

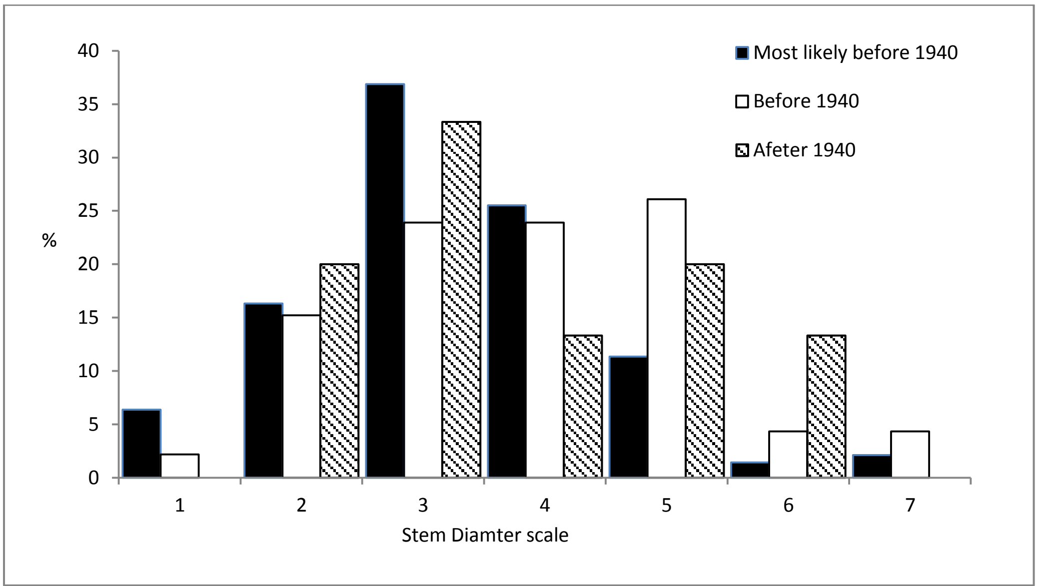
NLD=The Netherlands

WW=worldwide

Figure 4.2.13b. 'Bold Shoots' scales distribution referring to year of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

The most common Stem diameter scale for accessions bred most likely before 1940 and after 1940 was 3, which indicates stem diameter of 30-35 mm. For the accessions that were bred before 1940 the highest percentages were found in scale 5 which indicates 40-45 mm trunk diameter (26.08%). The percentages for scale 3 and 4 were a bit lower but almost equal (Figure 3.14a).

a) *Distribution referring to the cultivation year (%)*



b) *Distribution referring to the cultivation yea (observations)*

Score	Most likely before 1940	Before 1940	After 1940
1	9	1	0
2	23	7	3
3	52	11	5
4	36	11	2
5	16	12	3
6	2	2	2
7	3	2	0
Total	141	46	15

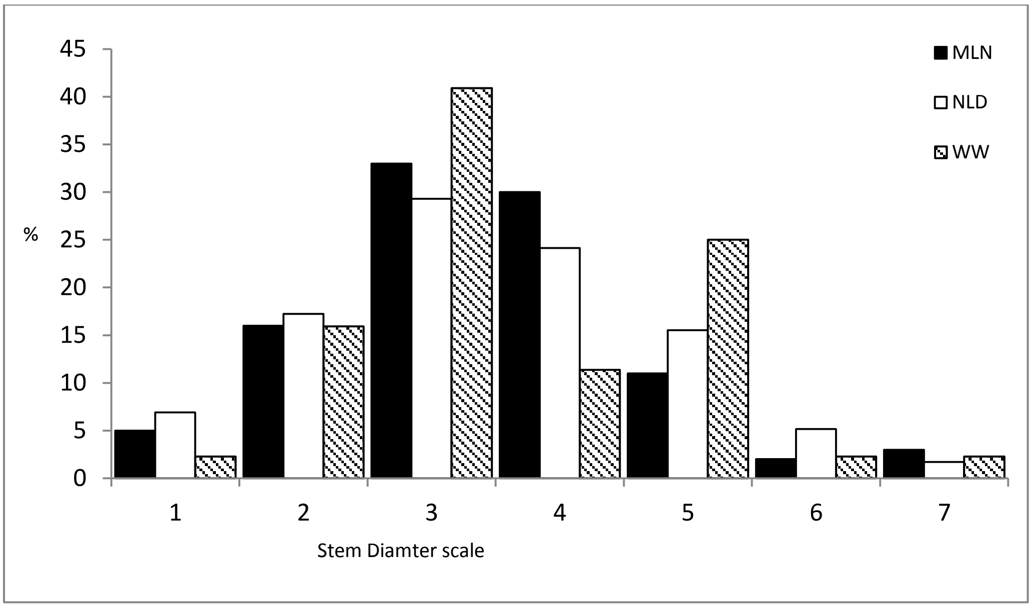
c) stem diameter scale in mm.

Scale	Stem diameter (cm)
1	20-25
2	25-30
3	30-35
4	35-40
5	40-45
6	45-50
7	50-55

Figure 4.2.14a. Stem diameter scales distribution referring to year of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

For all origin' categories scale number 3 was the most common (figure4.2.14b). However, worldwide origin' accessions were found in high numbers in scale 5 that indicates a stem diameter of 40-45 mm.

a) Distribution referring to the origin (%)



b) Distribution referring to the origin (observations)

Score	MLN	NLD	WW
1	5	4	1
2	16	10	7
3	33	17	18
4	30	14	5
5	11	9	11
6	2	3	1
7	3	1	1
Total	100	58	44

c) stem diameter scale in mm.

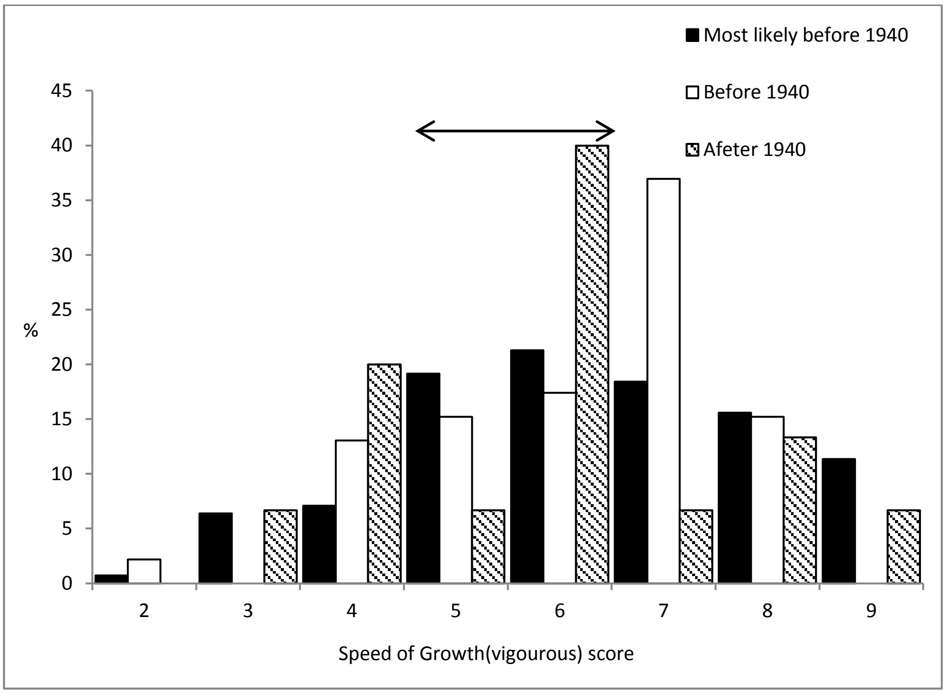
Scale	Stem diameter (mm)
1	20-25
2	25-30
3	30-35
4	35-40
5	40-45
6	45-50
7	50-55

MLN=most likely Netherlands .NLD=The Netherlands, WW=worldwide

Figure 4.2.14b. Stem diameter scales distribution referring to the origin of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

Speed of growth distribution of accessions that were most likely bred before 1940 is speared in a moderate way with a slight preference for scale number 6. Accessions that were bred after 1940 were mostly found in category number 6. The accessions that were bred before 1940, category number 7 was the most common (4.2.15a). The speed of growth indicates the vegetative growth of the tree and therefore the optimal score for the organic sector is 5-6.

a) *Distribution referring to the cultivation year (%)*



←→ Indicates the range of the preferably scales for organic growers

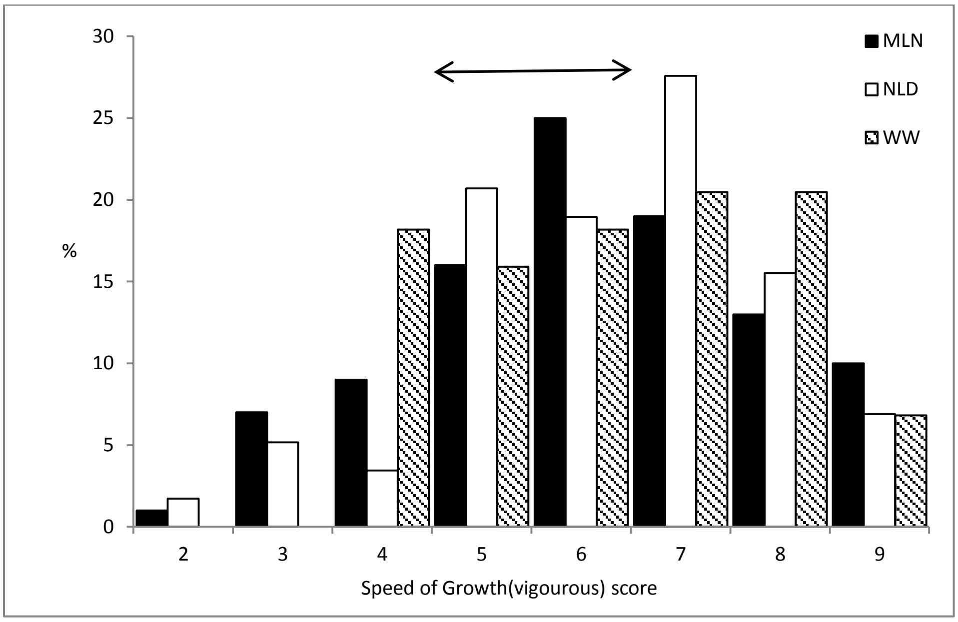
b) *Distribution referring to the cultivation year (Observations)*

Score	Most likely before 1940	Before 1940	After 1940
1	0	0	0
2	1	1	0
3	9	0	1
4	10	6	3
5	27	7	1
6	30	8	6
7	26	17	1
8	22	7	2
9	16	0	1
Total	141	46	15

Figure 4.2.15a Speed of growth scales distribution referring to year of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

The most common scale for most likely Netherlands accessions was 6 (25%), Netherlands 7 (27.59%) and worldwide accessions equally distributed between 7 and 8. (20.45%). The Dutch accessions were found in high numbers (20.68%) in the 5 scale. This speed of growth is preferred for the organic apple growers.

a) *Distribution referring to the origin (%)*



←→ Indicates the range of the preferably scales for organic growers

b) Distribution referring to the origin (observations)

Score	MLN	NLD	WW
1	0	0	0
2	1	1	0
3	7	3	0
4	9	2	8
5	16	12	7
6	25	11	8
7	19	16	9
8	13	9	9
9	10	4	3
Total	100	58	44

MLN=most likely Netherlands

NLD=The Netherlands

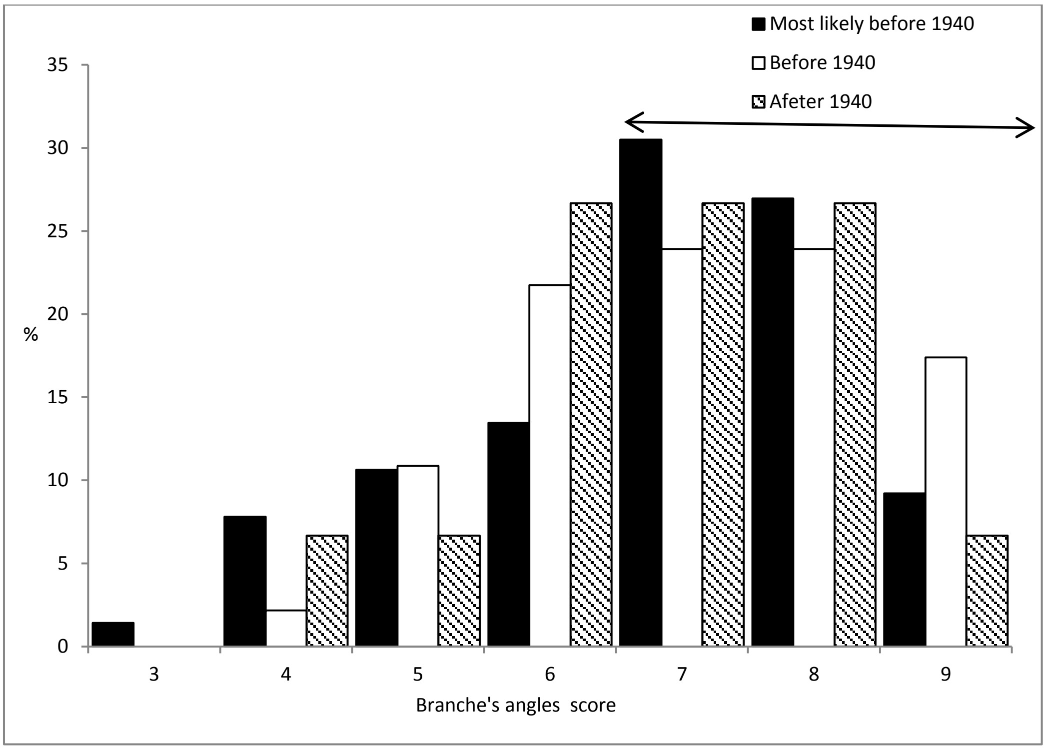
WW=worldwide

Figure 4.2.15b Speed of growth scales distribution referring to origin of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

The score of 7 for angles of the branches on the main trunk was the most common for the accessions that were most likely bred before 1940 (30.5%), 7 and 8 for the accessions bred before 1940 (23.91%)

and 6,7 and 8 for the accessions bred after 1940. The highest percentages of accessions scored with 9 were found within the accessions that were bred before 1940 (17.39%) which are the optimal score for the organic sector (Figure 4.2.16a).

a) Distribution referring to the cultivation year (%)



←→ Indicates the range of the preferably scales for organic growers

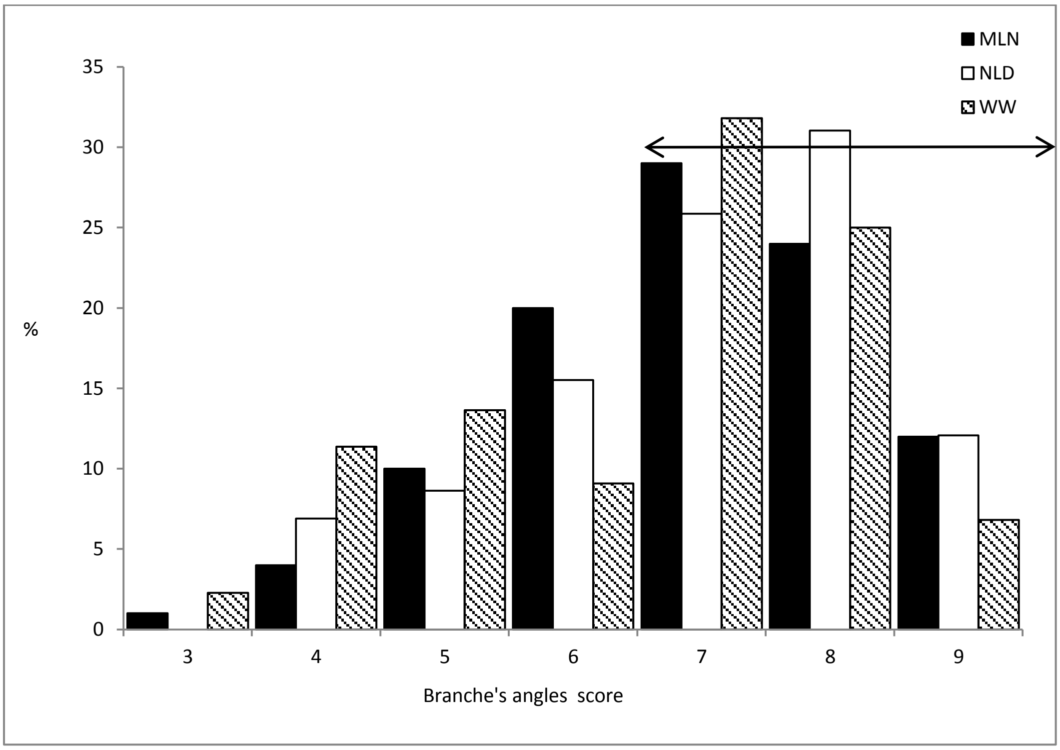
b) Distribution referring to the cultivation year (observations)

Score	Most likely before 1940	Before 1940	After 1940
1	0	0	0
2	0	0	0
3	2	0	0
4	11	1	1
5	15	5	1
6	19	10	4
7	43	11	4
8	38	11	4
9	13	8	1
Total	141	46	15

Figure 4.2.16a Angles of the branches on the main trunk scales distribution referring to year of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

The most common score of the branches angles for accessions that were most likely bred in the Netherlands and worldwide origin was 7 while most of the Dutch accessions were scored with 8. The highest percentages of the score 9 was found within the Dutch and most likely Netherlands accessions (~12%). (Figure4.2.16b). The angles of the branches affect the yield and are highly important for pruning methods due to time consuming and labour cost.

a) Distribution referring to the origin (%)



←→ Indicates the range of the preferably scales for organic growers

b) *Distribution referring to the origin (Observations)*

Score	MLN	NLD	WW
1	0	0	0
2	0	0	0
3	1	0	1
4	4	4	5
5	10	5	6
6	20	9	4
7	29	15	14
8	24	18	11
9	12	7	3
Total	100	58	44

MLN=most likely Netherlands

NLD=The Netherlands

WW=worldwide

Figure 4.2.16b. Angles of the branches on the main trunk scales distribution referring to origin of cultivation. The results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

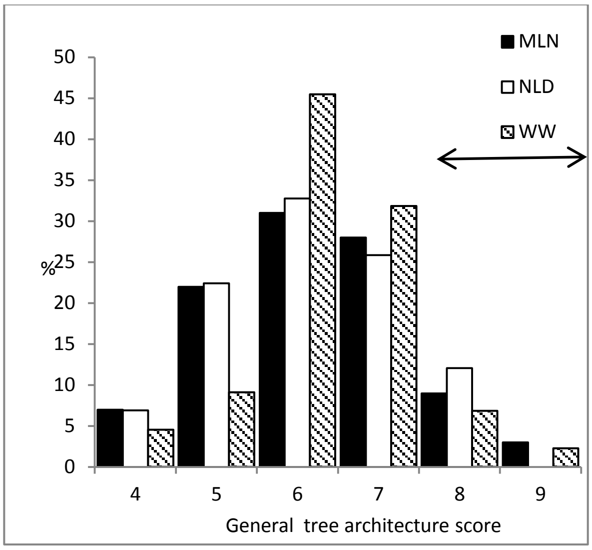
The differences in general architecture score reveal the general score for ‘bold branches’, number of new shoots, angles of branches, symmetry distribution of the angles, speed of growth and the ratio between the width of the main trunk and the branches.

Cultivars that bred after 1940(46.66%) and most likely before 1940(34.75%) were found in high percentages with the score of 6. 26.96 % of the cultivars bred before 1940 were scored with 7, which is the most common score for this category (Figure 4.2.17). None of the cultivars that were bred after 1940 got the score of 9. Three cultivars that were bred most likely before 1940 and one cultivar that was bred before 1940 was scored with 9 (the optimal score for the organic sector). Cultivars bred after 1940 were found in low percentage under the score of 8 as well.

For all origins a score of 6 was the most common score. 12.07 % of the Dutch accessions got the score of 8 which is the relative highest percentages compare to the other groups. However, none of the Dutch accessions got the score of 9. Three most likely Netherlands accessions and one accession from worldwide were scored with 9.

a) *Distribution referring to the cultivation year (%)*

c) Distribution referring to the origin (%)



b) Distribution referring to the year (observations)

Score	Most likely before 1940	Before 1940	After 1940
4	9	3	1
5	26	10	3
6	49	14	7
7	37	17	3
8	17	1	1
9	3	1	0
Total	141	46	15

←→ Indicates the range of the preferably scales for organic

c) Distribution referring to the origin (Observations)

Score	MLN	NLD	WW
4	7	4	2
5	22	13	4
6	31	19	20
7	28	15	14
8	9	7	3
9	3	0	1
Total	100	58	44

MLN=most likely Netherlands.

NLD=The Netherlands, WW=worldwide

Figure 4.2.17 General architecture distribution referring to year of cultivation and the origin. For each category the results shown as percentage out of the total observation within the category and the tables below indicated the actual observations.

Table 4.2.1 Mean comparison of the important agronomic traits for the organic sector between accessions bred before and after world war II.

	Accession cultivated before 1940			Accession cultivated after 1940			Difference
Traits	#observations	Mean	S.Deviation	#observation	Mean	S.Deviation	P value
Architecture score (Rank 1-9)	46	6.52	1.07	15	6.33	0.98	0.55
Angles scores (Rank 1-9)	46	7.09	1.35	15	6.80	1.32	0.47
Speed of growth (Rank 1-9)	46	6.15	1.41	15	5.87	1.69	0.52
Trunk diameter (mm)	46	34.84	5.04	15	36.20	7.13	0.42
Brix (% sugar)	32	14.48	1.88	10	14.90	2.03	0.55
Yield (Rank 1-5)	46	1.98[a]	1.41	15	3.55[b]	1.92	0.001*
Canker (Symptoms)	46	0.13	0.26	15	0.20	0.25	0.36
Powdery Mildew (0-9)	46	0.72	1.05	15	0.73	0.96	0.96
Scab (0-9)	46	0.54	0.89	15	0.13	0.52	0.10

[ab] Different letters indicate significant difference between the group's means.

* Significant difference (p value <0.05) with L.S.D =0.92.

Table 4.2.2 Mean comparison of the important agronomic traits between accession with Dutch (NLD) origin and accession from worldwide (WW).

	Netherlands			Worldwide			Difference
Trait	# observations	Mean	S.Deviation	# observations	Mean	S.Deviation	P value
Architecture score (Rank 1-9)	58	6.21	1.02	44	6.25	1.10	0.84
Angles scores (Rank 1-9)	58	7.02	1.40	44	6.59	1.56	0.15
Speed of growth (Rank 1-9)	58	6.09	1.50	44	6.23	1.54	0.63
Trunk diameter (mm)	58	35.90	5.26	44	35.75	7.23	0.91
Brix (% sugar)	48	14.72[a]	1.90	20	13.75[b]	1.25	0.04[1]
Yield (Rank 1-5)	58	2.47[a]	1.50	44	1.73[b]	1.97	0.03[2]
Canker (Symptoms)	58	0.17	0.27	44	0.15	0.22	0.71
Scab(0-9)	58	0.38	0.79	44	0.32	0.74	0.69
Mildew(0-9)	58	0.85	1.12	44	0.80	1.07	0.82

[ab] Different letters indicate significant difference between the group's means

[1] Significant difference (p value <0.05) with L.S.D=0.93

[2] Significant difference (p value <0.05) with L.S.D =0.68

General descriptions of the best cultivars performances

The accessions that showed the relatively best performance for all of the chosen traits according to the tree ideotype that suites for organic growers are presented in table 4.2.3. The accessions were chosen with threshold scores of 7 for General Architecture, 4 for Taste, 4 for Yield and 0 for Combine Disease Susceptibility, in order to represent the best 10% of the population.

Two out of six accessions that performed high results for all traits are Dutch origin, two are most likely the Netherlands, one is French and one from Kazakhstan and with the following distribution for accessions that perform high results for 3 traits; Netherland (5), most likely the Netherlands (12), Belgium (1), Great Britain (1), Canada (1) and France (1).

Table 4.2.3.Accessions with the relative best performances of the important traits to organic apple growers in the CGN collection, 2011.

Accession name	Architecture[1]		Taste		Yield		Disease Susceptibility	
Kaz 96 03-05(KAZ[2])	✓	(8)[3]	✓	(4.0)	✓	(4)	✓	(0)
Gen 174 (U)	✓	(7)	✓	(4.5)	✓	(4)	✓	(0)
Delgollune (FR)	✓	(7)	✓	(4.0)	✓	(4)	✓	(0)
Lunterse Present(NLD)	✓	(7)	✓	(4.0)	✓	(4)	✓	(0)
Rembrandt(NLD)	✓	(7)	✓	(4.0)	✓	(4)	✓	(0)
Renette van Grathem (U)	✓	(7)	✓	(4.0)	✓	(4)	✓	(0)
GEN 160 (U)	✓	(8)	✓	(4.5)	✓	(5)		-
Belle de Lunteren (NLD)	✓	(8)	✓	(4.5)	✓	(4)		-
Peperappel (U)	✓	(7)	✓	(4.0)	✓	(5)		-
Gen 208 (BEL)	✓	(8)	✓	(4.0)		-	✓	(0)
John Downie (GBR)	✓	(7)	✓	(4.0)		-	✓	(0)
Present van Hien (NLD)	✓	(7)	✓	(4.0)		-	✓	(0)
Schneeappel (CAN)	✓	(7)	✓	(4.0)		-	✓	(0)
GEN 171 (U)	✓	(7)	✓	(4.0)		-	✓	(0)
Royal Beauty (U)	✓	(8)		-	✓	(4)	✓	(0)
Dessert (NLD)	✓	(7)		-	✓	(5)	✓	(0)
Dolgo (U)	✓	(7)		-	✓	(5)	✓	(0)
Malus "Dolgo"(U)	✓	(7)		-	✓	(5)	✓	(0)
Malus Evereste (FR)	✓	(7)		-	✓	(5)	✓	(0)
Malus Ola (U)	✓	(7)		-	✓	(5)	✓	(0)
Malus Prof. Sprenger (NLD)	✓	(7)		-	✓	(5)	✓	(0)
Red jade (U)	✓	(7)		-	✓	(5)	✓	(0)
GEN 169 (U)	✓	(7)		-	✓	(5)	✓	(0)
Adams(U)	✓	(7)		-	✓	(4)	✓	(0)
Mc Laughlin(U)	✓	(7)		-	✓	(4)	✓	(0)
Limburgse Bellefleur (NLD)	✓	(7)		-	✓	(4)	✓	(0)
Deljuga (U)			✓	(4.0)	✓	(4)	✓	(0)

[1] The hierarchy of this table is organized by the importance of the agronomic traits for the organic sector in the following order: Architecture: Taste : yield=disease resistance

[2] Origin country (NLD=Netherlands, U=unknown, BEL = Belgium, FR=France ,GBR=Great Britain ,KAZ= Kazakhstan)

[3] Accession were chosen to be presented with the following score threshold: architecture (7), taste (4), yield (4) and disease resistance (0).

Principal compound analysis (PCA)

In order to analyze the multivariate data collected in this research a PCA was conducted. The main goal of PCA is to reduce a dataset in a multidimensional space into fewer meaningful dimensions in order to explain observed similarities and dissimilarities (Iezzoni & Pritts, 1991, Eriksson, 2001). It is based on the calculation of correlations between variables (each trait is a variable). The PCA try to explain the clustering of the different accessions and the correlation between the traits based on their variance. Therefore, in order reduce the variance impact of traits that scored on a different scales variance the data was standardized to the same scales. Yield for instance was standardized to the scale 0-9 although it was originally scored between 0-5. The traits that were chosen to be analyse by PCA, had to be without any missing values and not a component traits (general architecture for example). The Traits (loadings) are presented in table 4.2.4 and show the relative effect on the accessions clustering.

The first two axes in figure 4.2.18a, b, that best explain the variance (PC1=19.98%, PC2=15.66%) are explaining 35.64% of the variance. The Loadings (traits) that contribute the most for the clustering of different accessions on the first axis (PC-1) are new shoots re-growth (0.57), bold shoots (0.54) and branches angles (0.52). Pc 2 is explained by yield (0.68), speed of growth (0.51) and scab (0.45) (table 4.2.6). The biplots that are shown in figure 4.2.18a, b present the accessions according to their year of cultivation and their origin.

Clear clustering behaviour obtained for cultivars bred after 1940 with three exceptional accessions, Kaneelzoet (accession #30), Geelzoet (accession #15) and Jan Steen (accession #34) (all Dutch origin). Another biplot, labelled with accessions numbers, was conducted in order to locate the exceptional accessions (appendix III). The exceptional accessions are marked on the figure below (4.2.18a). However, there is no clear clustering easy to obtain for the cultivars that were bred before or most likely before 1940. Accessions that were bred after 1940 are characterized with relative high scores for new shoots, bold shoots and branch angles. The exceptional accessions performed lower scores for those traits and more susceptible for Scab and Powdery mildew and as mentioned before they were all bred in the Netherlands. The distribution of the accessions may give an indication about the reduction of the gene diversity. In the fig 4.2.18a the accessions that were bred before and most likely before are speared more equally in the space while the accessions bred after 1940 are concentrated at one area (marked on the graph as cluster of accessions bred after 1940).

The same biplot was conducted for accessions according to their origin (figure 3.18b). The biplot contained the same loadings with the difference of marking the different accessions with an origin labels instead of cultivation year labels. The distribution of Dutch and most likely Netherlands is equally speared and no clustering is easy to obtain it seem that those two groups represents large percentage of the traits diversity especially the ‘most likely Dutch’ group. In the worldwide origin, however, is relatively easier to obtain a cluster. The clustering is concentrated in the centre of the biplot with two roups of exceptional accessions (marked on figure 4.2.18b). The first group, Kaz 96 03-11(accession #128) and Kaz 95 17-14 (accession #156) (The top part of the biplot) is characterised by low yield and slow speed of growth those accessions are probably land races or wild species. Group II of the exceptional accessions are characterised by high yield and vigour growth. Florina (accession #91), bred after 1940 in France and Hillieri was bred in Great Britain and most likely before 1940. (Accession #177).

It is possible to see positive or negative correlation between traits based on the axes in the biplot which suggest that axes with same coordinates affect certain accessions to be related (Eriksson, 2001). Therefore all the axes that look relative close were examine with a linear regression analysis in order to obtain any correlation between the traits with relatively close axis (Table 4.2.5).

Positive correlations were found between Angles and Bold shoots *(P value=0.01*), Angles & New shoots (*P value<0.01*), Yield & speed of growth. (*P value =0.03)*, Bold shoots & new Shoots (*P value<0.01*). Positive correlation means that when a curtain accession scored high for ‘bold shoots’, for instance, it is likely that the same accession scored high for its angles. Opposite correlation was found between Scab & Yield (*P value =0.02*), which means that for a high susceptibility accession for scab the yield was low and other way around. Axes that seems to be close to each other, Speed of growth &scab (*P value*=0.75) and Scab & Powdery mildew (*P value*=0.75) were not found correlated to each other.

Table 4.2.5. Correlations between the measured traits at the CGN collection

Traits	Correlation	*P value*
Angles & bold shoots	+	0.01
Angles & new shoots	+	<0.01
Yield & speed of growth	+	0.03
Scab &Yield	-	0.02
Bold shoots & New Shoots.	+	<0.01
Speed of growth & Scab	No	0.75
Scab &Powdery mildew	No	0.75

(+)= Positive correlation, (-) = Opposite correlation, (No) =No correlation.

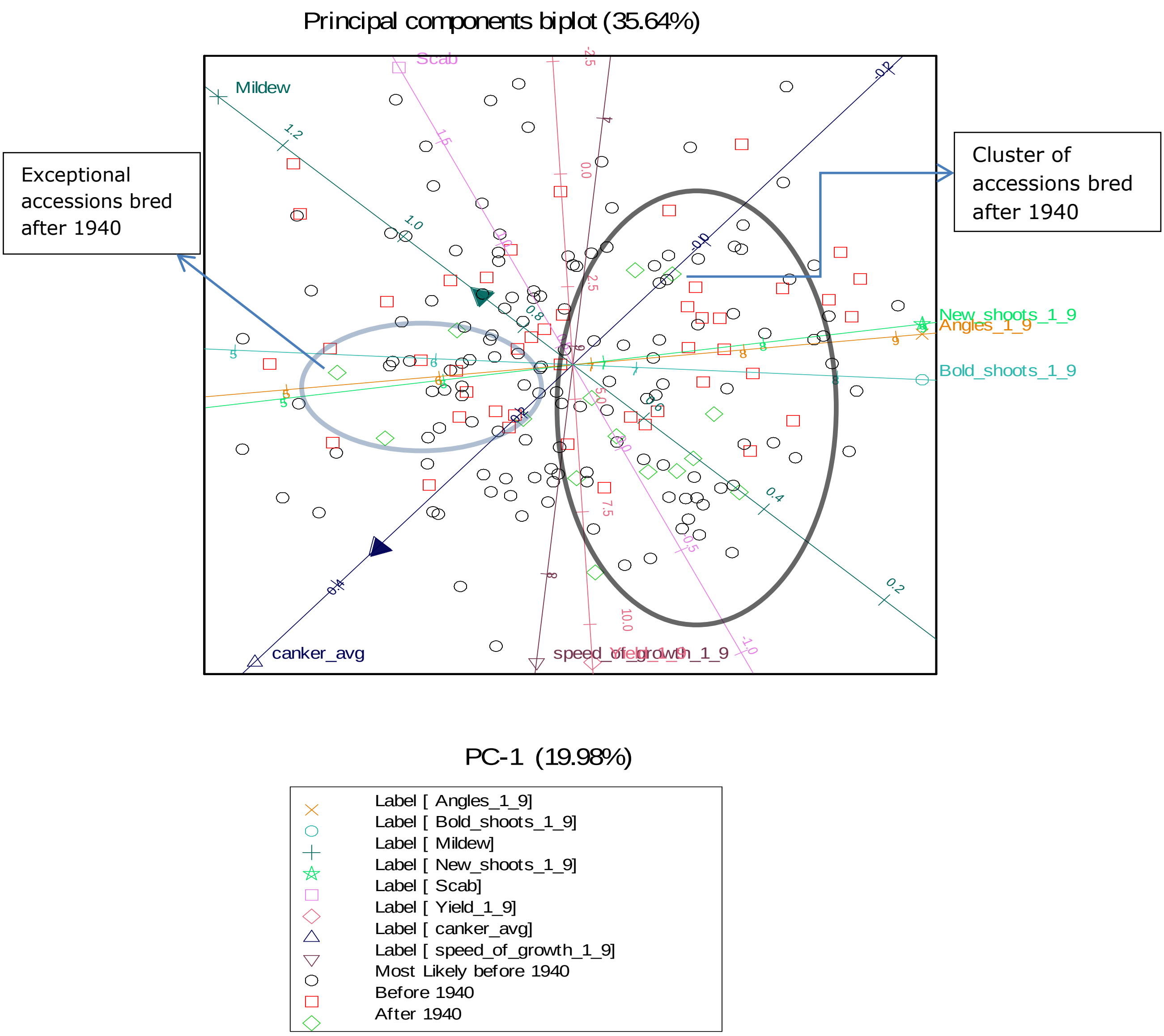


Figure 4.2.18a. PCA of the measured traits at the CGN collection referring to year of cultivation.

Table 4.2.6 .The loading scores of the 2 first PC axes

Loading(traits)	PC 1	PC 2
Angles_1_9	0.52	0.05
Bold_shoots_1_9	0.54	-0.03
Mildew	-0.10	0.09
New_shoots_1_9	0.57	0.08
Scab	-0.22	0.45
Yield_1_9	0.04	-0.68
canker_avg	-0.22	-0.24
speed_of_growth_1_9	-0.05	-0.51

- The full loading scores can be found on appendix III.

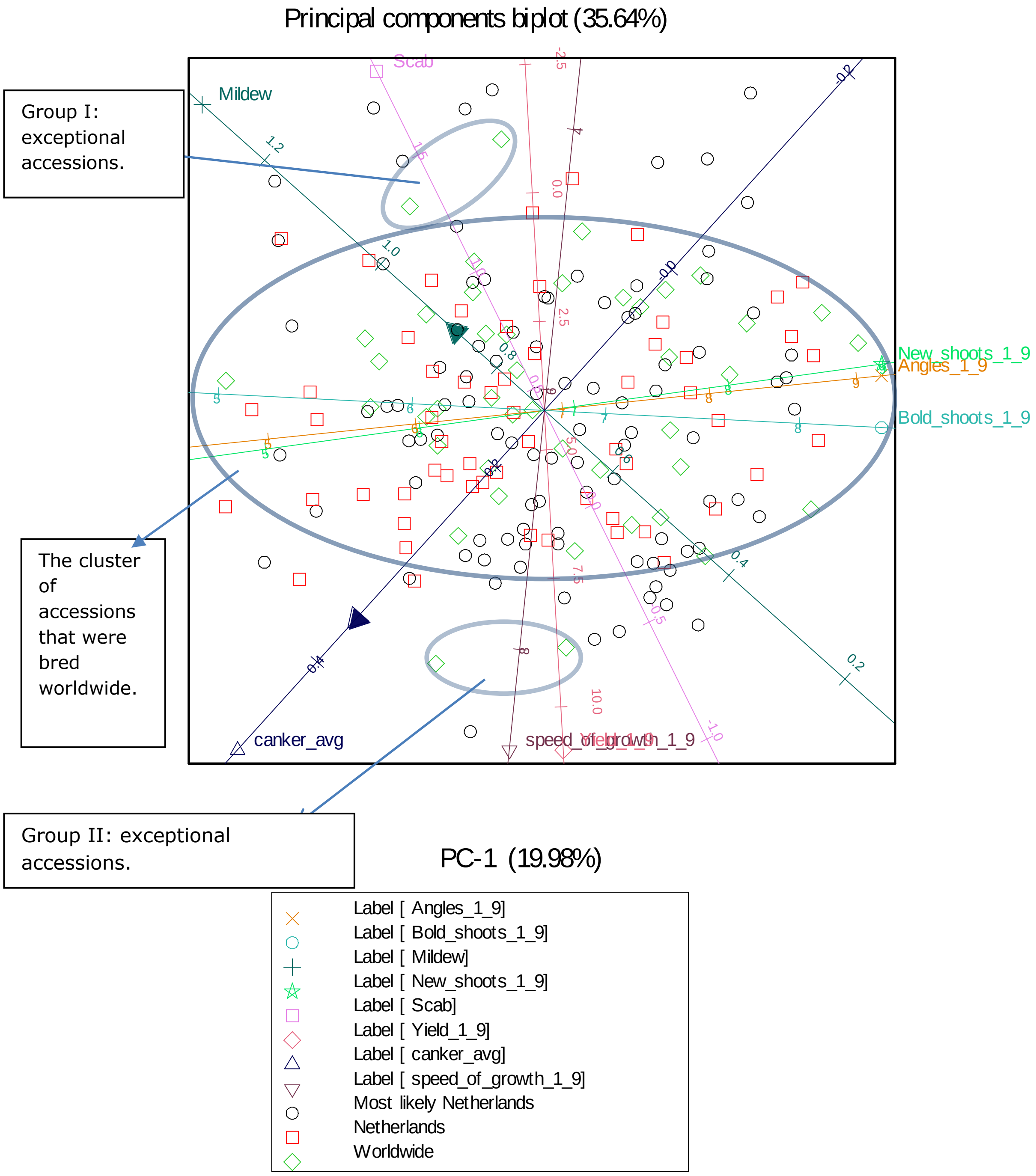


Figure 3.18b PCA of the measured traits at the CGN collection referring to year of cultivation.

4.2.2. Architecture comparison within the same accessions evaluated in different collections

A comparison between the accessions in three different collection, the CGN, Noordelijke Pomologische Vereniging and the Pomologische Vereniging Noord-Holland collection was done in order to obtain patterns in architecture traits which influenced by the different collection environment and practices.

The three different collections differ in location (climate, soil etc...), pruning methods, rootstocks, pesticides and fungicides application, nitrogen application and the age of the tree. Tree architecture traits are strongly affected by those parameters. All architecture traits were analysed using unbalanced design analyse of variance due to missing accession in one of the collections. 28 accessions from the CGN, 24 accessions from Noordelijke Pomologische Vereniging collection and 21 accessions from Pomologische Vereniging Noord-Holland collection were analysed. In Table 4.2.7 the Angles of branching scores comparison between the different accessions are presented.

Angles of the branches is the variate that were chosen to be presented here due to the lack of the collection influence on the angles score (*p value = 0.645*) and the significant difference between the cultivars (*p value = 0.041*) in branches angles and with L.S.D score of 1.7. General architecture score shows significant collection difference (*p value = 0.003*) and no difference between cultivars (P value = 0.124). Bold branches shows collection and (*p value = 0.011*) and cultivar (*p value = 0.042*). New shoots do not show collection (*p value= 0.629*) and neither cultivar (*p value = 0.228*) difference. Speed of growth has no significant influence of variety (*p value=0.098*) and collection (p value= 0.998). Average of new shoots growth (cm) and main trunk diameter were not analysed due to the reason of large variance of those traits, because of the differences in grafting methods between the collection and the unknown age of the trees in the Noordelijke Pomologische Vereniging collection, which are important parameters to determine the speed of growth.

Table 4.2.7. Comparison between cultivars in different collections (CGN, *NPV and PVN).*

Accession name	#observations	Mean	S.Deviation
Cwastresse Double	2	6.5	0.71
Dijkmanszoet	3	7.7	0.58
Framboosappel	3	7.3	0.58
Gamerense Zure	2	6.5	0.71
Glorie van Holland	3	7.7	0.58
Glorie van Veendam	2	8	1.41
Groninger Kroon	3	6.7	0.58
Groninger Peppeling	2	6	1.41
Jacob Dirk	2	8.5	0.71
Jan Steen	2	5.5	0.71
Jasappel	2	6	0.00
Lemoenappel	3	5.3	0.58
Lombarts Calville	3	8	1.00
Lunterse Pippeling	3	7.3	2.08
Notarisappel	2	5.5	2.12
Oranje Renette	2	7	1.41
Peperappel	2	5.5	0.71
Present van Engeland	3	6.5	0.71
Present van Hien	3	7	1.73
Princesse Noble-1	3	6.7	0.58
Reinette Rouge Etoilée	3	5.7	0.58
Renette Ekenstein	2	7	0.00
Rode Tulpappel	3	6	0.00
Schellinkhouter	2	8	0.00
Streepjesappel	2	6.5	0.71
Valkappel	2	5.5	0.71
Zigeunerin	3	6.7	1.53
Zoete Kroon	2	7.5	0.71
Zoete Pippeling	2	6	0.00
Zure van Driebergen	2	8	1.41

[1] Different letter indicates significant difference between accessions.
L.S.D=1.7 (*P value= 0.041*).

4.2.3 Additional data sets analysis and disease susceptibility.

Scab and Powdery mildew

Scab and powdery mildew evaluations, Blommers (1983) and CGN Evolutions that were made in 1999 and 2007, are used here in order to give wider and more deeply comparison in addition to the assessments made on September, 2011. However the results that presented here reflect a lot of interactions between the different parameters which are not known due to the lack of information of the evolutions from the past years. In order to analyse different data sets all ranking were standardized to the same ranking method. Disease susceptibility comparison between Dutch accessions, according to observations from 1977-1982 ,1999 and 2011, shows significant interaction between years of evaluation and accessions for both Powdery mildew (p *value* $= 0.009$) and Scab (p *value*$=0.05$). Significant cultivar difference found in Powdery mildew (p *value* < 0.001) and not significant in scab (p *value*$= 0.367$). Clear difference according to the years of evaluations in both powdery mildew (P *value*<0.001) and scab (p *value*<0.001) was found. The year of evaluation does not reflect only the difference of the year (climate, different soil conditions etc.) but also the different location. In 1999, 2007 and 2011 the collection was located in Randwijk, while in 1978 - 1980 the collection was located in TNO, Zeist. Furthermore the collection in Randwijk is planted every 10 years on a fresh soil and therefore the evaluations from 1999 and 2007 were done at a different location from 2011 and different tree ages.

The accessions were observed according to their location in the orchard (appendix IV). According to the map it is clear to see if there were centres of infections which can explain the effect of the year by different centres of diseases infestation. According to the map it is possible to see few centres of diseases susceptibility and it is important to regard to this map while deciding whether a certain cultivar has a disease resistance or not.

Canker

Canker evaluation was observed by the CGN in 1999 and 2007 in Randwijk. The results were analysed in one data set together with the current evaluation. In order to analyse the different data sets, all data were standardized to the same scale of scoring. Due to the cultivars rearrangement during the years in the CGN collection only 79 same cultivars were evaluated three times (1999, 2007 and 2011) and other 52 cultivars twice (2007 and 2011). According to the analysis, there was a significant difference between the accessions (*p value = 0.08*) However, a clear difference between the years was found (*p value<0.001)* and presented in the table below (table 4.2.8). The trees are replanted every 10 years in Randwijk but on a different soil (1998, 2008 etc.) and therefore, the year can indicate different climate, susceptibility to canker according to the age of the tree, different centres of infestation and different soil condition.

Table 4.2.8. Difference of canker susceptibility between the years.

Year	Canker score
1999	0.72b[1]
2007	1.17a
2011	0.41c

[1]Differnt letters indicates significant difference.
L.S.D.=0.2279.

The accessions were observed according to their location in the orchard (appendix IV) and it is visible to see centres of the infestation for Canker as well. The accessions that got infected might be located in the infected area and does not have necessarily no resistance to canker and vice versa.

5. Heritability

In a broad sense, heritability can be defined as the ratio between the genotypic variance and the phenotypic variance. Hence, genes that correspond to visible traits have stronger influence than the environment on the trait expression. However, in extreme environmental condition the environment can suppress the gene effect (Segura et al., 2006). Therefore breeders can only select genetically inherited traits in order to achieve significant genetic improvement. The equation for heritability is expressed as: $h^2 = \frac{\sigma^2 G}{\sigma^2 P}$, where h^2 stands for the heritability value, σ^2G is the genetic variance and σ^2P is the phonotypic variance. According to Gallais (1989) a trait is heritable if the value of heritability is higher than 0.2.

Heritability definitions can be accurate only for specific population and environments (Souza et al., 1998). The genetic background of a population can affect the phenotypic expression of certain traits transmitted to the next generation. For instance if both parents are homozygous for a certain trait with different alleles, the individuals of the F1 generation will all display heterozygous genotypes. Apple cultivars are known for their heterozygous genomes and therefore the results of heritability tests are relatively reliable (Segura et al., 2006).In addition, the quantitative distributions of the studied traits suggest a probable polygenic control and, in this case, the probability that all genes responsible for trait expression are homozygous for the two parents is very low (Segura et al., 2006).

Disease resistance

The heritability for scab resistance was checked and estimated as moderate (0.3). However this result is sufficient enough for the development of new cultivars with durable resistance for apple scab (Bus et al., 2002). Vf, the major gene that correlated with resistance to apple scab, together with 10 other independent loci (Va, Vb, Vbj, Vfh, Vg, Vh2, Vh4, Vjomib, Vm, and Vr) constitute the gene map for scab resistance. However, dissemination of a virulent scab race which overcame some of genes resistance was described (McHardy, 1996). Therefore, novel apple breeding strategies should be searching for a cultivar with different gene combination to develop offspring displaying durable resistance (Bus et al., 2002).

Most studies showed that five major genes are associated with powdery mildew resistance (Pl-1, Pl-2 Pl-w, Pl-dfrom and Pl-m). Usually monogenic resistance is easily introgressed into new cultivars, but it easily takes a few generations to combine resistance traits with other agronomic traits of interest. Moreover, monogenic resistance can be overcome by more virulent pathogens strains. Therefore polygenetic resistance may be integrated as a more durable alternative as mildew resistance is controlled by 4-5 QTLs (Calenge & Durel 2006). However the polygenetic resistance has not yet been proven to reduce significantly chemical pesticides application and therefore a combined resistance of monogenetic and polygenic resistance is recommended. The heritability for both types of resistance is high (Calenge & Durel 2006).

Architecture

Segura et al. (2006) conducted a heritability research on apple tree architecture. The densities, angles, flexibility and shapes of shoots on branches and on the main trunk were measured. Tree branching variables heritability values were close to 0.4. In addition the categories for measuring those traits were divided into two shapes categories: topological (growth, density etc.) and geometric shape (angles shape, etc.). Architectural traits seem to be correlated to each other within and between each category. Poor correlations were measured between the number of shoots on the main trunk and the number of shoots on the branches. Trunk vigour was estimated by the circumference of the trunk and its heritably value was 0.51 (Durel et al., 1998).

An important phenomenon is a "columnar tree", mutant of the cultivar Mcintosh, which has short internodes and axillary buds growing mainly into spurs and rarely into lateral branches. Most studies suggested that Co, a single dominant gene, is associated with this phenomenon (Meulenbroek et al., 1998). Therefore Co seems to have pleiotropic effect on a few architecture traits and might hide other architecture traits (Kenis & Keulemans 2004).

Fruit quality

Fruit quality traits are largely studied. Silva et al. (2007) found high heritability values for fruit diameter (h^2=0.47), with a mean weight of fruit (h^2=0.6) and a fruit production (kg/ha) (h^2=0.78), indicating that those traits are inherited to a great extent. Heritability value of post-harvest softening level - which indicates the storability - was found to be 0.55 (Iwanami et al., 2008).

6. Discussion

It highly important to mention start from the beginning that the comparisons that presents here are not well represented the different groups (origin and year). The accessions, especially 'Worldwide' and 'Bred after 1940' accessions, were chosen selectively, based on specific traits. However, the comparisons can indicate general trends and characters of the different group.

According to tree ideotype it is clear those conventional cultivars such as 'Elstar', which is representative of a vigorous tree, do not fit into the organic growers needs. In addition to traits of interest for organic growers and consumers (high quality fruits and suitable cultivar to low input conditions), this study highlight the importance of tree architectural traits. However, according to the organic breeders and growers, it seems that those traits were discarded during the development of the modern cultivars currently in use in the Netherlands.

This study was undertaken to investigate the heritage of a long tradition in apple cultivation in the Netherlands and the wish of the organic sector to value this heritage by the development of a cultivar specially adapted to the local conditions. A population composed by 202 accessions originating from the CGN collection was evaluated to find out the characteristics to be taken into account when devising an ideotype for the organic apple market (with the emphasis on Dutch origin).

The evaluation of the population using an improved methodology included a detailed scoring of fruit quality, tree architecture, diseases susceptibility and yield production, and showed promising potential for future breeding perspective.

Nearly 25% (7 accessions) of the best 10% best performing cultivars were Dutch cultivars. Moreover, the cultivars of unknown origin, constituting nearly 50% from the list, were most likely to be Dutch or have become part of the local apple tradition. However, the PCA results showed that a group of 42.85% of the Dutch accessions, bred after 1940 scored low for architectural traits such as 'bold shoots', 'new shoots' and 'angles of the branches' and showed relative high susceptibility for powdery mildew and scab. This might be a consequence of neglecting those traits in the modern Dutch breeding programs.

The comparison between Dutch cultivars and worldwide cultivars showed that the Dutch cultivars have higher yield production and sugar (Brix %) levels than other cultivars. These results can be explained by better adjustment of the local cultivars to soil and climate conditions. A large group of cultivars of worldwide origin was found in the class of 100% fruit drop (intense fruit drop), reflecting the different timing of ripeness outside the Netherlands. However, no significant difference was recorded between the Dutch accessions and the cultivars of foreign origin for all the other important agronomics traits. Another possible explanation can therefore be that those cultivars were collected according to special agronomic traits and not necessarily in favour of their yield or sugar level performances. For example, a large interesting group of accessions originating from Kazakhstan was found with high diseases resistance, vigorous growth and very green leafs (indicating a NUE), but produced low yield.

A second comparison between old and new cultivars was conducted based on the work of Van Treueren (2010), who indicated that the trend in apple breeding changed from fruit quality to yield production after World War II. Although it is considered that new cultivars exhibit better disease resistance, there was no significant difference between the two groups for that trait. The only clear difference was obviously yield production (table 4.2.3). However in some categories, as fruit appearance, the narrowing down of the traits was visible. In some cases, the narrowing down reflected the preference of the consumers for desirable traits like red over colour, which was found in high percentage in cultivars released before 1940, and not necessarily associated with the negative effects of the narrow gene pool use by most breeding programs as mentioned in the introduction (Noiton&

Alspach, 1996). Fruit shapes and sizes results clearly revealed the preference for the shape 3.1 (table 4.2.3a) in the new cultivars, which can be correlated with consumers wishes, transportation and storability reasons. For accessions released before 1940 the size and shape distribution is more equally spread. The yield production was found significantly higher for cultivars bred after 1940 in comparison to those who bred before 1940. Those trends highlight the strategy of current breeding programs focusing on fruit production and marketing. Disease susceptibility results showed higher percentages of cultivars displaying no symptoms for powdery mildew (figure 4.2.8) and canker (figure 4.2.10) in cultivars released before and most likely before 1940, while in scab the relative amount of cultivars without symptoms were higher in the population of cultivars released after 1940. These results might give an indication about the focus on scab resistance in the recent apple breeding programs (after 1940). Scab and powdery mildew are regularly sprayed with fungicides, but for canker no chemical treatments was applied and those results can indicate a relatively higher resistance to canker in the old cultivars (71.4% of accessions released before 1940 had no canker symptom, while 53.33% of the accessions released after 1940 had no canker symptom). Although there was no significant difference in fruit quality, tree architecture and disease susceptibility traits in this study it is important to emphasize that this project examined only the accessions that could be found at the CGN collection, and therefore may not be representative of a larger set of cultivars.

Branch angle comparison between the accessions on different collections (Table 7) suggested that there was no environmental influence on this traits, although the collection were located in different areas, were managed differently and were applied different levels of inputs (irrigation, fertilizer), the only significant difference found among the accessions was branches' angles. This may explain that the architectural trait' polymorphism within the accessions is strongly determined by genotype and less by the environmental effects.

The PCA results suggested correlations between several architectural traits as 'angles' and 'bold shoots' *(P value=0.01*), 'angles' and 'new shoots' (*P value<0.01*), 'bold shoots' and 'new shoots'. (*P value<0.01*). These results can be explained by pleiotropic effects on a few architecture traits as suggested by Kenis & Keulemans in 2004. The implication of pleiotropic genes on a breeding program for architecture improvement is dual: on one hand many accessions performed high architecture results in different categories and not necessarily in all of them, therefore it will be difficult to introgress those traits due to the influence one of a single gene. On the other hand, the improvement of many traits can be achieved by focusing on one gene.

The analysis of canker results showed differences in infection and diseases susceptibility over different years and no clear difference between the accessions. Possible explanation for that can be due to different climate conditions such as rainfall quantity and number of rainfall days (Beresford&Kim, 2011). Another explanation can be correlated to age of the trees. The trees were planted in 1998 and replanted in 2008, while the highest level of canker symptoms were recorded in 2007 when the trees were much older than those on which other measurements were done. During the growth, a tree develops more branching and shoots which creates more possibilities for closure of eco-systems. These kinds of environments are suitable for the development of canker as mentioned before (Simon et al., 2006).

An additional data set was collected by Blommers in 1983 and was used for giving a deeper insight into disease susceptibility .In the same data set, yields were recorded under low and high inputs. In the current CGN collection there are only 10 similar cultivars but this study can give an indication about cultivars' performance under organic and low input management practices if a new study under such conditions is carried out in the future at the CGN.

This project may be the starting point for a broader characterisation project and data validation of cultivars performance. Validation refers to the procedure before the data analysis, and includes evaluation of the traits reproducibility on a following years, diverse locations and users. (Jacques et al., 2003). The stability of certain characteristics such as disease resistance, yield production, and architecture has to be assessed in a different environment to conclude about GxE interactions and trait polymorphism. In order to analyse the data efficiently, it is important to work under the same standards and procedures of evaluation. As Van Treueren (2010) mentioned, current uncertainty in some accessions' names, should be investigated as well in the future.

The results presented here, together with the data base that will be available at CGN and at the Louis Bolk institute, can give another perspective on the n large diversity of phenotypes existing among the Dutch apple cultivars, and suggest an innovative methodology for apple accessions assessment based on Lateur's work (Lateur et al., 2010).

Many countries have difficulties in maintaining the large apple collection managed by government founding (Nybom & Garkava-Gustavsson 2009). However, in the Netherlands, in addition to the CGN collection, many other pomological associations and private collectors are interested in collecting cultivars with special traits. The curators of these collections hold a great deal of knowledge about the accessions' characteristics and the pruning methods in their collection. The pruning strategies differ from one cultivar to another and the importance of pruning frequency, age of the trees and shape designed to fruit quality and yield production is crucial. This valuable knowledge can give additional value to the data collected in this project.

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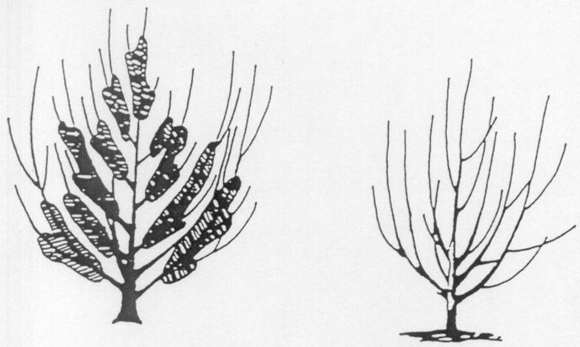
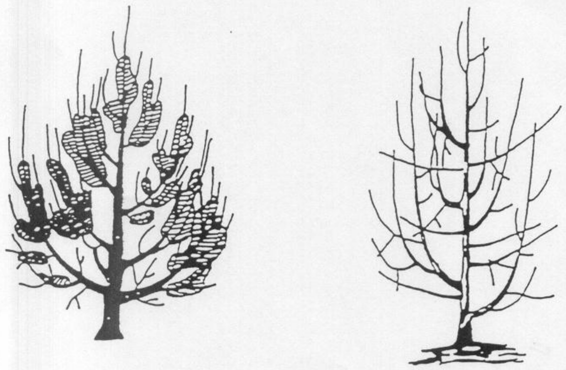
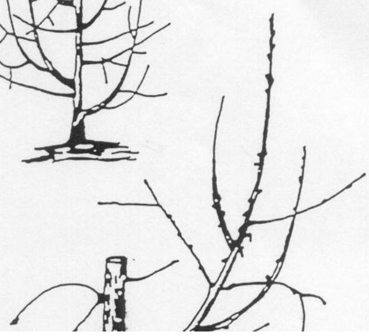
7.Annexes

7.1.Appendix I – EUFRIN Tree architecture descriptor

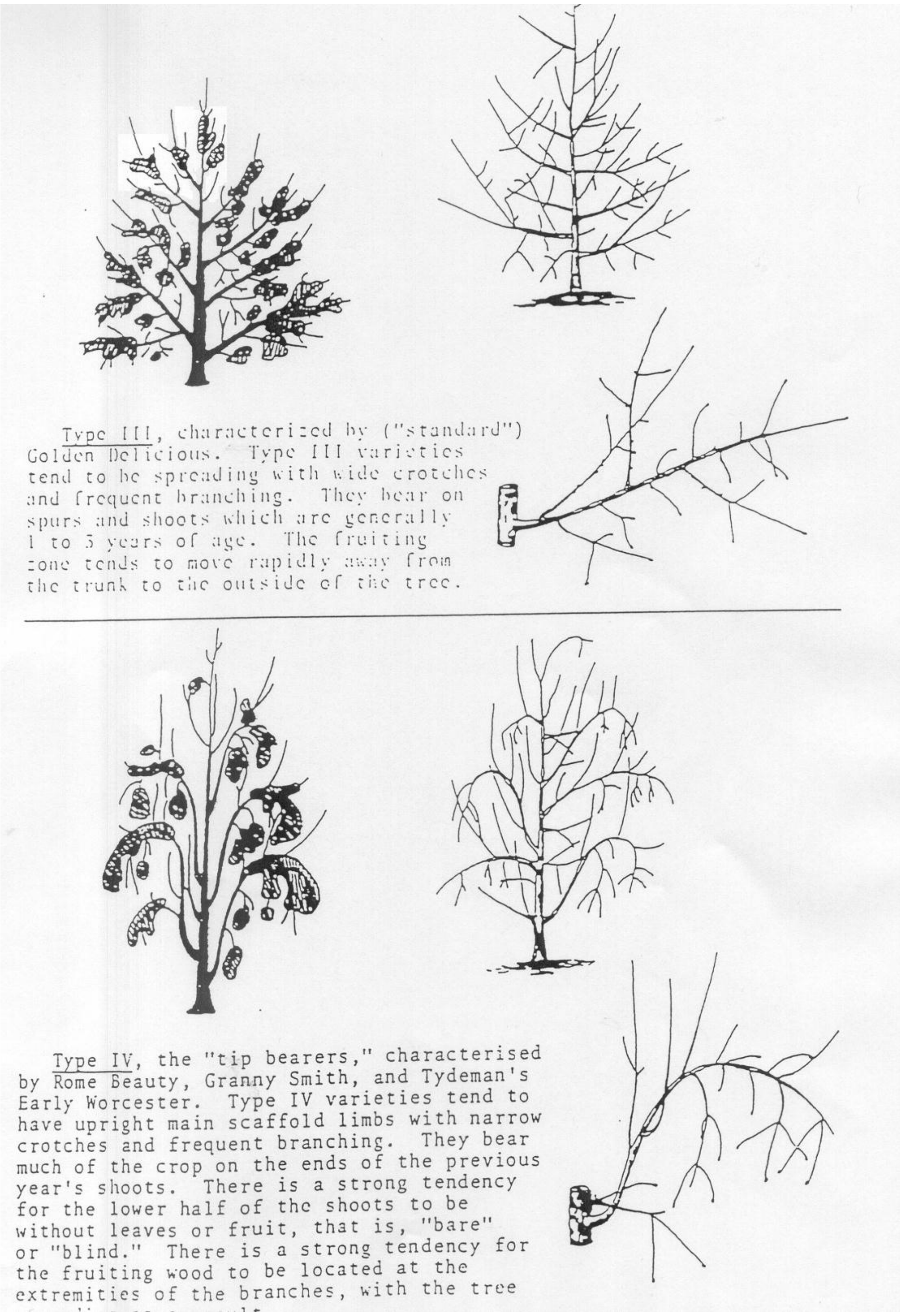


Type I, spur types, characterized by Starkrimson Delicious. Type I trees tend to be upright with narrow crotches and sparse branching. Fruiting occurs on numerous short spurs which are long lived. The zone of fruiting tends to remain close to trunk.





Type II, characterized by King of the Pippins. This is a variation of type I in which branching is more frequent and there is a greater tendency for the fruiting zone to move away from the trunk.



Type III, characterized by ("standard") Golden Delicious. Type III varieties tend to be spreading with wide crotches and frequent branching. They bear on spurs and shoots which are generally 1 to 3 years of age. The fruiting zone tends to move rapidly away from the trunk to the outside of the tree.

Type IV, the "tip bearers," characterised by Rome Beauty, Granny Smith, and Tydeman's Early Worcester. Type IV varieties tend to have upright main scaffold limbs with narrow crotches and frequent branching. They bear much of the crop on the ends of the previous year's shoots. There is a strong tendency for the lower half of the shoots to be without leaves or fruit, that is, "bare" or "blind." There is a strong tendency for the fruiting wood to be located at the extremities of the branches, with the tree

(Figure 7.1 Architecture descriptor., EUFRIN website, 2011 based on Lespinasse, 1977)

7.2. Appendix II– Fruit Shape descriptor

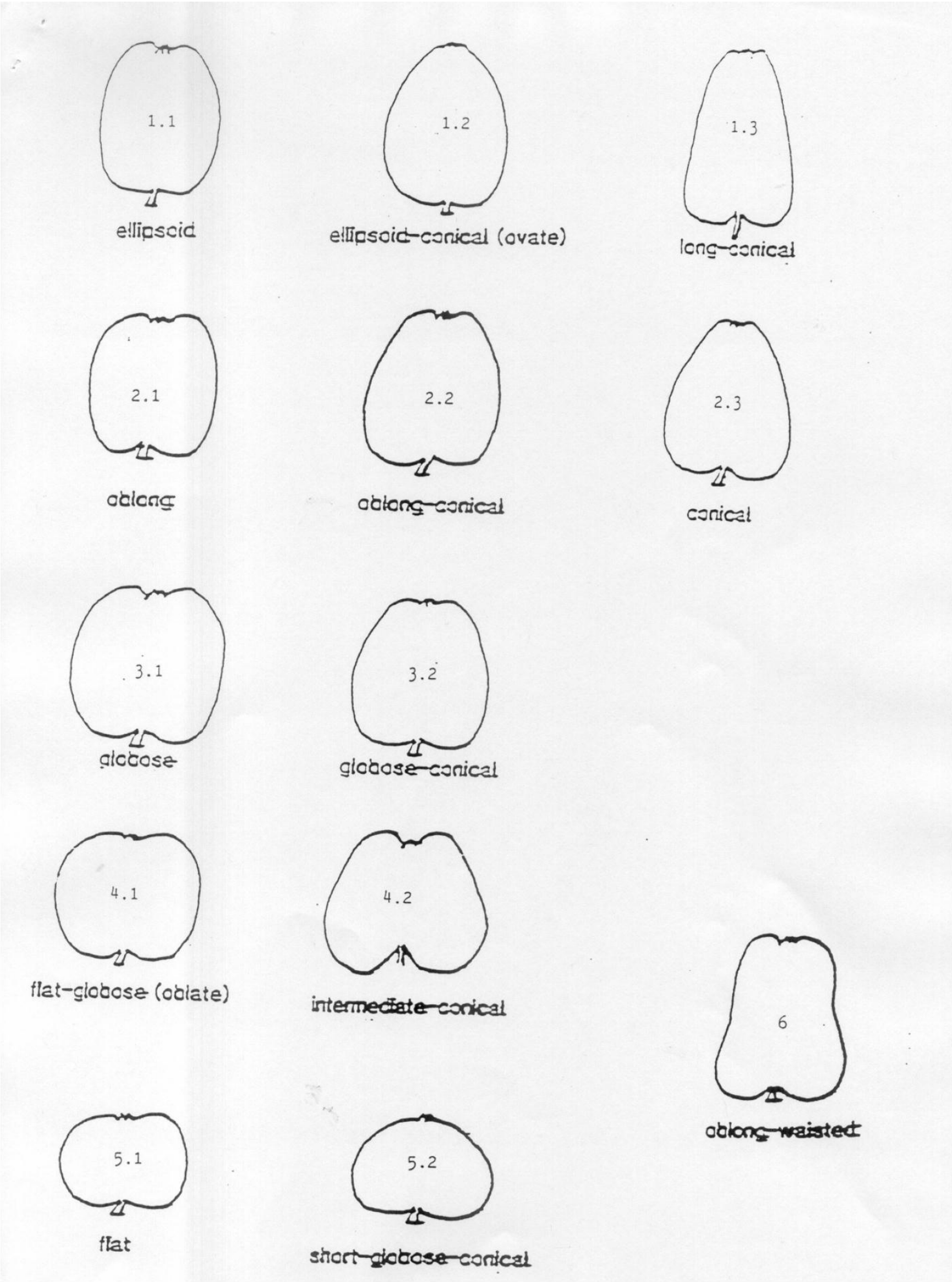


Figure.7.2 Fruit shape (EUFRIN,2012)

7.3.Appendix III- PCA additional results

The full loading scores

Latent vectors (loadings)

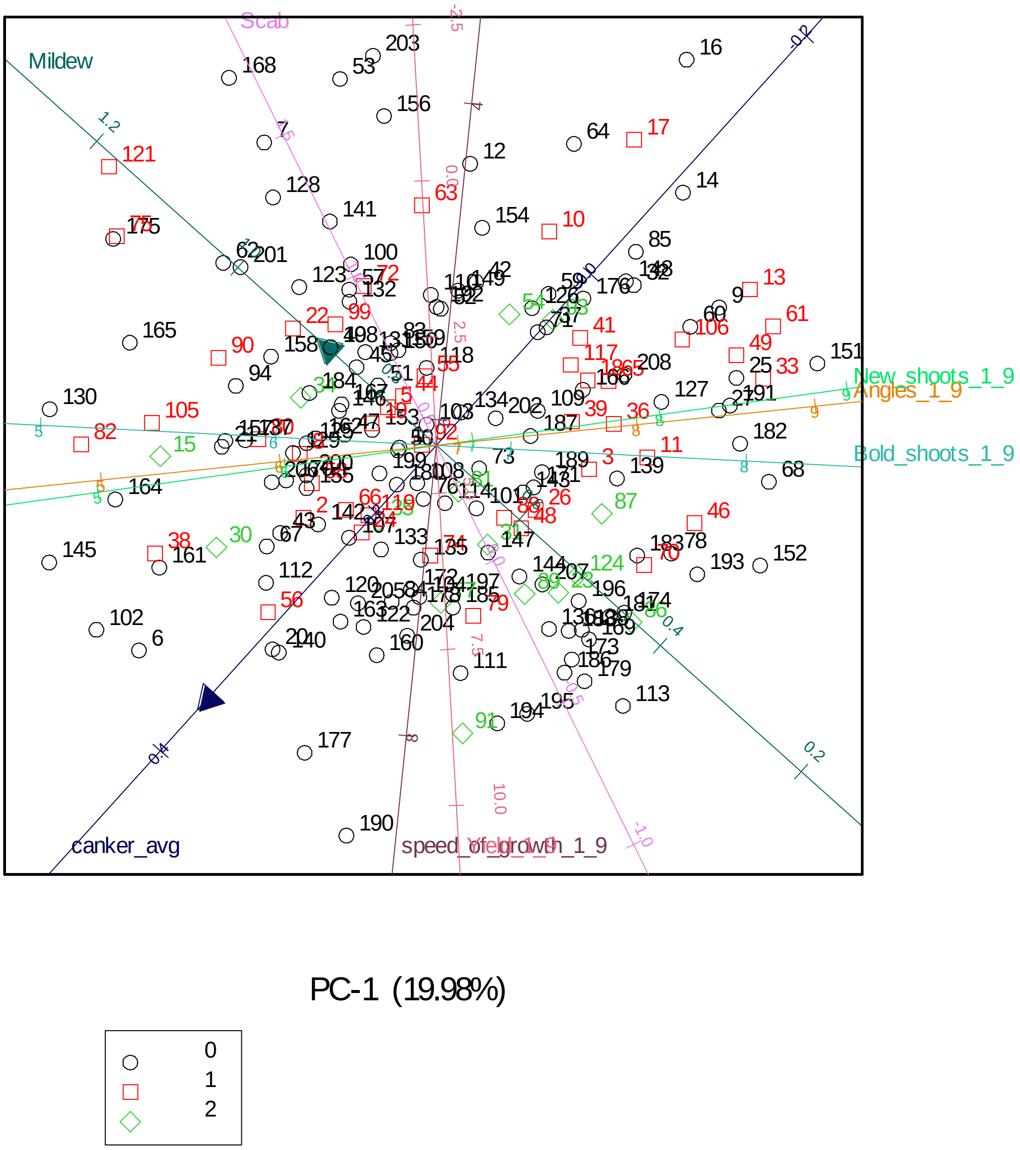
	1	2	3	4	5
Angles_1_9	0.51769	0.05358	0.00504	0.16274	0.02371
Bold_shoots_1_9	0.53939	-0.02744	-0.11738	0.03994	-0.08591
Mildew	-0.10242	0.09160	0.81295	-0.21370	0.42026
New_shoots_1_9	0.57398	0.07924	0.08731	0.09919	0.42957
Scab	-0.22470	0.45458	-0.40143	-0.01761	0.37499
Yield_1_9	0.03752	-0.67517	0.10400	-0.14841	-0.19335
canker_avg	-0.21546	-0.23863	0.09189	0.91121	0.20476
speed_of_growth_1_9	-0.05276	-0.51212	-0.37052	-0.25254	0.64108

	6	7	8
Angles_1_9	0.49703	-0.57350	0.35511
Bold_shoots_1_9	-0.03297	0.71753	0.41184
Mildew	0.15253	0.15257	0.22674
New_shoots_1_9	-0.20219	-0.00497	-0.64913
Scab	0.58961	0.27250	-0.13746
Yield_1_9	0.55660	0.18067	-0.36064
canker_avg	0.02477	0.10900	0.05890
speed_of_growth_1_9	-0.17223	-0.11904	0.28120

Bi plots

1. Accession labelled with their numbers referring to their year of cultivation.

Principal components biplot (35.64%)

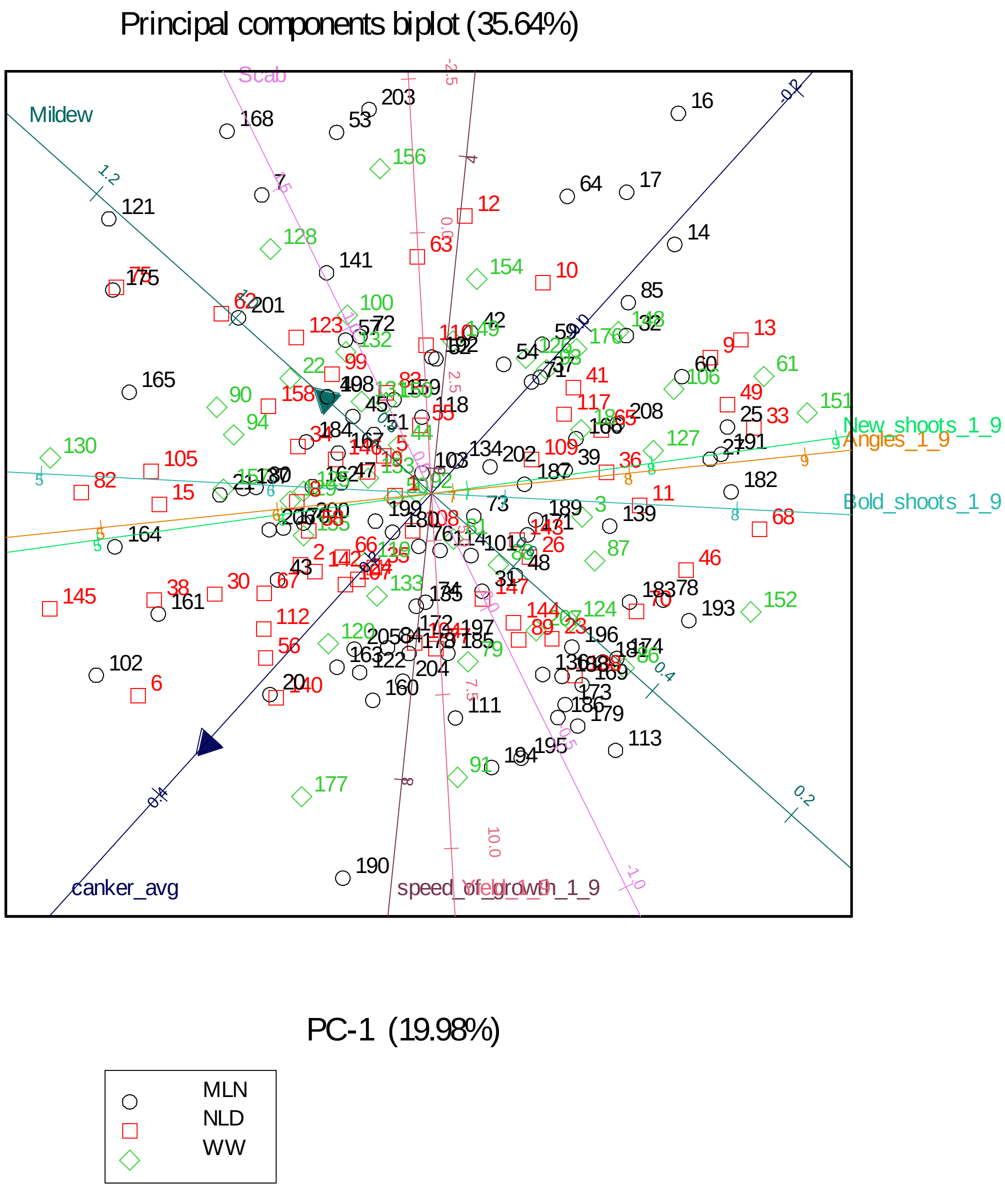


0 = Accessions bred most likely before 1940

1 = Accessions bred before 1940

2 = Accessions bred after 1940

2.Accession labelled with their numbers referring to their origin



MLN = Accessions bred most likely in the Netherlands.

NLD = Accessions bred in the Netherlands.

WW = Accessions bred worldwide.

7.4. Appendix IV– The CGN collection map regarding to diseases susceptibility.

Row 1			Row 2			Row 3			Row 4			Row 5		
Mildew	Scab	Canker	Mildew	Scab	Canker	Mildew	Scab	Canker	Mildew	Scab	Canker	Mildew	Scab	Canker
2.00	0.00	0.67	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	2.00	1.33	2.00	0.00	0.33	2.00	0.00	0.00	2.00	0.00	0.33	0.00	0.00	0.00
0.00	0.00	0.00	2.00	0.00	0.00	2.00	0.00	0.33	0.00	1.00	0.00	0.00	2.00	0.00
0.00	3.00	0.00	2.00	0.00	0.67	0.00	0.00	0.33	2.00	0.00	0.00	0.00	0.00	0.00
0.00	2.00	0.33	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.67
2.00	0.00	0.00	0.00	0.00	0.33	0.00	2.00	0.33	0.00	2.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	2.00	0.33	0.00	0.00	0.67	0.00	0.00	0.00	3.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	2.00	2.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	2.00	0.00	0.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
2.00	0.00	0.67	0.00	0.00	0.00	2.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00
0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.33	0.00	0.00	0.33
2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2.00	2.00	0.67	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	2.00	0.00	0.50	0.00	0.00	0.00
0.00	0.00	0.33	2.00	2.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.33
0.00	0.00	0.33	0.00	2.00	0.00	0.00	2.00	0.00	0.00	2.00	0.33	0.00	0.00	1.00
2.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00	0.00
0.00	0.00	0.00	1.00	0.00	0.33	2.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00
0.00	0.00	0.00	0.00	0.00	0.33	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.33
0.00	0.00	0.33	2.00	0.00	0.33	3.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	1.00	0.00	0.33
0.00	0.00	0.33	2.00	0.00	0.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	1.00	0.00	0.00	2.00	0.33	3.00	2.00	0.00	1.00	2.00	0.00
0.00	0.00	0.00	0.00	2.00	0.00	2.00	0.00	0.00	0.00	2.00	0.00	3.00	0.00	0.00
0.00	0.00	0.33	0.00	0.00	0.33	4.00	0.00	0.00	2.00	0.00	1.00	0.00	1.00	0.00
2.00	0.00	0.00	2.00	0.00	0.33	2.00	0.00	0.67	2.00	0.00	0.00	1.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	2.00	2.00	0.00	2.00	0.00	0.00	1.00	3.00	0.00
2.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33	0.00	0.00	0.50	2.00	0.00	0.50
0.00	0.00	0.00	0.00	2.00	0.00	1.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	2.00	0.00	0.00	1.00	0.00	0.67	0.00	2.00	1.50	1.00	0.00	0.00
0.00	0.00	0.00	0.00	2.00	0.33	2.00	0.00	0.33	0.00	0.00	0.33	2.00	0.00	0.00
0.00	0.00	0.00	2.00	0.00	0.00	2.00	0.00	0.00	2.00	2.00	0.00	0.00	0.00	0.00
0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	2.00	3.00	0.00			
2.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00			
2.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.33	0.00	0.00	0.00			

7.5. Appendix V- Accessions Data (Traits scores and evaluations)

Fruit quality, appearance and production traits scores (CGN collection,2011)															
Name	Accession #	Acidity: Sugar	Yield (0-5)	Fruit drop%	Shape	Diameter size(m)	Over colour	Over colour%	Brix	Sample	Colour	Firmness (1-9)	Taste 1-5	Ripeness level(1-9)	Skin (1-9)
Dijkmanszoet	1	1\1	2	20	3.2	75-80	Red	45	15	5	Yellow	4	4	4	4
Renette Ekenstein	2	2\1	1	100	2.2	80-85	red	30	14	1	Yellow	3	3.5	4	4
Schneeappel	3	1\1	2	70	1.2	90-95	Red	50	15	5	Yellow	4	4	4	4
Groninger Peppeling	5	1\1	1	60	2.1	70-75	Red	80	16.5	3	Yellow	2	3	8	4
Jasappel	6	1\2	4	10	2.2	75-80	Purple	30	13	5	Green	4	3	3	4
Langzoet	7		1	100						0					
Groninger Kroon	8	3\2	3	30	3.2	70-75	Red	80	16	5	Yellow	3	3	7	6
Gerrie Roelof	9	2\1	1	65	3.2	90-95	Red	10	12.5	3	Green	7	2	3	4
Schellinkhouter	10	2\1	2	10	1.3	75-80	Red	40	15	3	Green	3	4	4	6
Limburgse Bellefleur	11	3\2	4	10	3.1	90-95	Red	20	13	5	Green	7	2	3	7
Wijnappel	12		0	100						0					
Jacob Dirk	13	1\3	1	70	3.1	70-75	Red-Purple	80	13	5	Yellow	3	3	7	4
St.Japiksappel	14		0	100						0					
Geelzoet	15	1\2	3	40	3.1	75-80	x	x	15	5	Yellow	4	2.5	7	6
Onbek-1	16	2\1	1	80	3.2	65-70	x	x	12	2	Green	3	3.5	5	4
Sijden Hemdje	17		0	0						0					
Taunton Cross	18	1\2	1	0	4.1	85-90	Red	70	15	1	Yellow	2	2	8	4
Notarisappel	19	1\3	1	90	2.2	90-95	Red	40	15	4	Green	3	3	6	4
Groninger	20	1\1	4	30	1.2	70-75	Red	90	13	5	Yellow	1	1	8	3
Paradijsappel	21	1\3	3	60	4.1	95-100	Red	70	11	5	Yellow	6	4	3	5
Zigeunerin	22		1	50						0					
Dessert	23	1\3	5	10	4.1	90-95	Red-Purple	80	14	5	Yellow	3	2.5	7	4
Echtelds Zoet	24	1\2	2	50	3.1	70-75	x	0	15	5	Green	6	4	5	5

Eersteling	25	3\1	4	40	4.2	90-95	Red	40	14	4	Green	4	3	4	4
Glorie van Veendam	26	3\1	2	70	3.2	85-90	Red	50	10	5	Green	4	2.5	4	4
Zaailing 82	27		1	100						0					
Kaneelzoet	30	1\3	2	35	4.1	70-75	Brown	95	19	5	Green	4	3	4	4
Sevenum Striefke	31	2\3	3	30	3.1	75-80	Red	80	16	5	Green	5	3	4	5
Paradijs Bedieze	32	3\2	2	65	4.2	75-80	Purple	90	14	5	Green	5	4	3	5
Zoete Winterkroon	33	1\2	2	50	4.1	75-80	Red-Purple	70	17	5	Yellow	3	2	7	4
Jan Steen	34	1\1	1	70	3.1	75-80	Purple	100	15	4	Yellow	3	2.5	6	4
Balder	35	1\2	4	30	4.2	85-90	Red-Purple	80	14	5	Yellow	4	4	5	5
Pomme Rosa	36	1\1	3	30	3.1	75-80	Red	75	15	5	Yellow	3	2.5	5	4
Herfst Zoetzuur	37	2\3	2	60	2.2	90-95	Red	50	16	5	Green	5	4	4	4
Lunterse Pippeling	38	1\1	3	30	3.1	80-85	Brown	60	14	5	Yellow	4	4.5	4	4
Court Pendu-1	39	1\1	1	40	3.1	75-80	Red	80	18	1	Green	4	3.5	6	4
Groene Kroon	40	1\1	0	100	3.1	85-90	Brown	90	16	1	Green	6	4	4	6
Gamerense Zure	41	1\1	1	80	3.2	75-80	Red	50	13	2	Green	5	2.5	5	5
Streepjesappel	42		0	100											
Schoner von Wiltshire	43	2\3	3	20	4.1	90-95	Red	60	14	5	Yellow	4	3	5	4
Princesse Noble-2	44	1\1	2	80	2.2	65-70	Red	60	14	5	Yellow	4	3	6	5
Grasappel	45	2\1	2	60	1.2	60-65	x	0	15	4	Green	6	3.5	4	2
Present van Hien	46	1\3	3	50	3.2	100-105	Red	50	15	5	Green	5	4	4	4
Zoete Crombach	47		1	100											
Oranje Renette	48		2	80											
Glorie van Holland	49	2\3	2	60	3.1	75-80	Orange	50	15	5	Yellow	3	2	7	4
Winter Gravenstein	50		1	100											
Pomme Gilson	51	1\3	1	90	4.1		Brown	50	20	3	Green	6	2	4	4
Grote Zoete	52		1	100											
Druivenzuur	53		0	100											
Tonia	54		0	100											

Honingzoet	55		1	90											
Lemoenappel	56	2\3	2	70	3.2	90-95	Brown	60	19	5	Yellow	6	4	4	4
Pomme Duchene	57	1\1	1	90	4.1	75-80	Red	20	15	1	Green	5	4	4	3
Frambozenappel	58	1\2	2	80	3.1	80-85	Purple	60	15	5	Yellow	3	3	7	4
Wildling Herfstappel	59		0	100											
Zoete Paarswang	60	1\2	0	100	3.1	75-80	Red	50	15	4	Yellow	1		9	4
Zure Renette	61		0	100											
Gronsvelder Klumpke	62		0	100											
Rode Tulpappel	63		0	100											
Yellow Vincent	64		0	100											
Eysdener Klumpke	65		0	100											
Prinses Margriet	66	2\1	3	10	3.2	75-80	Red-Purple	90	14	5	Yellow	5	3	4	4
Kanappel	67	2\3	2	30	4.1	65-70	Red	50	19	4	Green	8	3	4	4
Lunterse Present	68	2\3	4	15	2.2	90-95	Red	30	12	5	Green	5	4	4	5
Belle de Lunteren	70	2\3	4	20	2.2	90-95	Red	50	14	5	Yellow	4	4.5	5	5
Zomerzuur	71	1\1	0	20	4.1	80-85	Red	60	13	1	Yellow	1	4	9	4
Court Pendu-2	72		1	70											
Renette d'Ernaut	73	2\1	4	10	4.1	90-95	Red	70	13	5	Green	5	3.5	4	6
Peperappel	74	1\2	5	10	2.1	65-70	Red	60	16	5	Green	7	4	4	4
Valkappel	75		0	100											
Zure van Driebergen	76	1\1	3	60	2.2	65-70	Red	70	14	5	Yellow	4	2.5	5	4
Rozenblaadje	77	2\1	5	10	3.2	80-85	Red	80	16	5	Green	2	2.5	8	4
Renette van Grathem	78	2\3	4	10	3.1	80-85	Red	70	15	5	Green	3	4	5	4
Princesse Noble-1	79	1\2	3	20	3.2	75-80	Purple	80	14	5	Green	7	3	3	4
April Eierappel	80	1\1	3	30	1.3	70-75	Red	75	14	5	Green	4	4	4	5
Jonwin	81	1\2	5	5	3.1	85-90	Red	80	14	5	Green	2	3.5	7	4
Present van Engeland	82	1\1	4	10	1.3	75-80	Orange	20	13	5	Yellow	4	4	4	4
Zaailing de Jongh	83	1\2	0	100											
DELGOLLUNE	84	2\3	4	5	2.2	90-95	Red	70	14	5	Yellow	5	4	4	4

Malus Golden Gem	85		0	100											
Malus Evereste	86	x	5	30	4.1	<45	Red	80	x	5	Orange	x		x	x
Golden Hornet	87		5	30	3.1	<45	Brown	80	x	5	Yellow	x		x	x
Gorgeous	88	x	5	5	3.1	<45	Red	70	x	5	Orange	x		x	x
Malus Prof. Sprenger	89		5	5	3.1	<45	Red	50	x	5	Orange	x		x	x
Grenadier	90		0	100											
Florina	91	2\3	5	10	3.2	80-85	Red	60	11	5	Yellow	5	4	4	5
Joseph Musch	92	3\2	3	20	4.1	100-105	Red	80	13	5	Yellow	5	3	4	6
Pristine	93		0	100											
Radoux	94	2\3	1	70	3.2	85-90	Red	60	13	5	Yellow	3	3	5	6
Reinette de Blenheim	95	2\3	2	60	3.1	95-100	Red	30	14	2	Green	3	2.5	5	5
Zaailing Leerbroek	96	1\1	3	20	3.1	80-85	Red	60	15	5	Yellow	3	4	4	4
Gelata	97	1\2	3	15	3.1	80-85	Red	10	16	5	Green	4	4	4	4
Malus Ola	98	x	5	5	3.1	<45	Red	70	x	5	Pink	x		x	x
Beemsterherfst	99	1\2	2	60	4.1	85-90	Red	90	17	5	Yellow	3	3	7	4
Cwastresse Double	100	1\2	0	100	2.1	90-95	Orange	80	15	1	Yellow	2	2.5	7	5
S XIII 1/30	101	1\1	3	70	3.2	80-85	x	x	14	5	Yellow	4	4.5	4	4
Reinette Hernaut	102	1\1	3	50	4.1	100-105	Red	80	11	5	Green	5	4.5	4	6
RGF 4	103	1\1	2	60	4.1	95-100	Red	60	15	5	Green	5	4	5	5
Woets	104	1\3	3	50	3.2	90-95	Red	90	15	5	Green	2	2.5	8	4
Beemstervroeg	105		0	100											
Angold	106	2\3	4	5	4.2	90-95	Red	40	12	5	Green	6	4	4	4
68 A	107	2\3	4	10	4.1	90-95	Red	60	15	5	Green	6	4.5	4	4
117	108	3\2	4	10	3.1	85-90	Red	70	13	5	Green	6	3.5	4	5
A 4	109	1\3	2	70	3.1	80-85	Red	60	14	5	Yellow	6	2.5	4	4
AK 2	110	1\2	3	60	3.2	90-95	Red	90	14	5	Yellow	2	3	6	4
Colapuis	111	1\1	4	10	3.1	70-75	Purple	80	11	5	Green	4	3.5	4	4
Zoete Elisabeth	112	1\1	3	20	4.2	90-95	Red	90	15	5	Green	6	2	3	5
Decio	113	1\2	5	10	3.1	85-90	x	x	15	5	Yellow	5	4	4	5

Durello di Forli	114	2\1	4	15	4.1	75-80	Red	30	13	5	Green	6	3.5	4	6
Lombarts Calville	117	2\3	4	10	1.2	80-85	x	x	11	5	Green	5	4	4	5
Oberrieder Glanzreinette	118	2\3	3	15	3.1	85-90	x	x	14	5	Yellow	6	4	4	4
President Roulin	119	1\2	3	50	5.1	100-105	Red	50	13	5	Green	4	3.5	5	4
Reinette Clochard	120	1\1	3	20	3.1	80-85	x	x	15	5	Green	3	3	5	5
Reinette Rouge Etoilée	121		0	10											
TNR 10-8	122	2\1	4	30	3.1	80-85	x	x	10	5	Yellow	4	2.5	4	4
AK 5	123		2	70											
Alps Otome	124	1\3	5	15	1.1	45-50	Red	100	15	5	x	4	4	5	5
KAZ 96 08-16	125		0	100											
KAZ 96 07-06	126		0	100											
KAZ 95 05-06	127		0	100											
KAZ 96 03-11	128		0	100											
KAZ 95 18-18	129		0	100											
KAZ 93 35-01	130		0	100											
KAZ 96 07-04	131		0	100											
KAZ 95-10-01L	132		0	100											
KAZ 96 09-12	133	2\1	2	50	2.2	70-75	Red	30	14	5	Green	4	3.5	4	4
Saltanat	134	2\3	2	70	3.2	75-80	Purple	80	14	4	Yellow	5	4	4	4
CPRO 90045-133	135	1\3	3	15	2.2	75-80	Purple	70	17	4	Yellow	3	4.5	5	4
SIR-KEP 91-2	136	1\1	4	20	2.1	80-85	Red	70	14	5	Green	4	2	4	4
DL 26	137	1\2	4	10	4.1	80-85	Red	70	17	5	Yellow	5	4	4	4
Rembrandt	138	1\1	4	10	4.1	90-95	Purple	90	16	5	Yellow	5	4	4	5
Mc Laughlin	139	1\1	4	10	3.1	90-95	Red	70	16	5	Orange	3	3.5	5	4
DJ- 93-50	140	2\3	5	15	3.1	75-80	Orange	60	18	5	Yellow	5	4	4	5
Gele Zoete	141	1\2	0	100	3.2	85-90	Brown	60	16	2	Green	3	4	6	4
Prinses Marijke	142	1\1	4	15	3.1	80-85	Red	90	16	5	Yellow	4	3	5	5
Prins Bernhard	143	1\1	3	10	4.2	85-90	Red	80	14	5	Yellow	5	2.5	4	5
Prinses Irene	144	2\3	5	5	3.2	75-80	Red	70	12	5	Yellow	3	3.5	6	5

Prinses Margriet	145	3\2	4	10	4.1	80-85	Red	95	15	5	Green	4	3.5	4	5
Koningin Juliana	146	2\3	1	70	3.2	85-90	Red	60	14	4	Yellow	3	3.5	5	4
Prinses Beatrix	147	2\3	2	70	3.2	80-85	Red	60	16	5	Yellow	5	4	4	4
Kaz 95 10-04F	148		0	100											
Kaz 96 03-15	149	1\3	1	90	3.2	85-90	Red	80	15	1	Yellow	1	2	9	4
Kaz 96 08-17	150		0	100											
Kaz 95 06-08	151		0	100											
Kaz 96 03-05	152	1\1	4	30	3.2	80-85	Red	100	14	5	Green	4	4	4	4
Kaz 96 06-02	153		0	100											
Kaz 96 03-07	154		0	100											
Kaz 95 17-14	155	2\3	5	5	3.2	75-80	Red	80	14	5	Green	6	4.5	4	4
Kaz 96 03-11	156		0	100											
Kaz 96 08-15	157		0	100											
85	158	2\3	3	60	2.3	75-80	Red	60	15	5	Yellow	4	4	4	5
A 588	159	1\2	3	60	1.2	80-85	Red	90	13	5	Yellow	2	3	7	4
FAW 12556	160	1\1	5	10	3.2	80-85	Red	60	13	5	Green	4	4.5	4	4
HL 885	161	1\2	4	10	3.2	75-80	Red	60	16	5	Yellow	4	3.5	4	4
ISF-FO 89.30.2	162	1\1	2	80	3.1	70-75	Red	80	16	4	Yellow	5	4	4	4
Perlyna Kieva	163	1\1	4	20	4.1	100-105	Purple	80	13	5	Green	6	3.5	4	4
Santaro	164	1\1	4	40	3.1	95-100	red	90	14	5	Yellow	4	4	4	4
Siostra Liberty	165		0	100											
SJC 658 (01-1054)	166	1\1	1	90	3.2	85-90	x	x	15	2	Yellow	2	3	7	4
SJC 7441-1	167	2\1	2	80	4.1	85-90	x	x	14	4	Yellow	4	3	4	4
UEB 3290/1	168	1\2	2	20	3.2	55-60	Red	90	14	5	Orange	2	3	5	3
UEB 3322/5	169	1\3	5	15	3.2	85-90	Red	100	17	5	Yellow	3	3	5	4
UEB 3375/2	170		3	10											
YX 24	171	2\3	3	15	2.2	80-85	Red	80	16	5	Green	6	4	4	4
CPRO 87017-37	172	1\3	3	15	3.2	75-80	Red	90	19	5	Green	2	3	6	4
Deljuga	173	1\2	4	10	3.2	70-75	Red	65	16	5	Yellow	3	4	4	5

R17T034	174	1\3	4	10	3.1	80-85	Red	75	14	5	Green	4	4.5	5	4
88-24/13	175	2\3	2	20	4.2	95-100	Purple	90	14	3	Yellow	4	4.5	4	4
John Downie	176	1\2	0	100	3.2	80-85	x	x	14	5	Yellow	4	4	5	4
Hillieri	177		5	100											
Malus "Dolgo"	178		5	100											
Dolgo	179		5	100											
Adirondack	180		5	15											
Royal Beauty	181		4	20											
Malus "Aldenham Purple"	182		0	100											
Malus Coronaria	183	4\1	3	50	4.1	45-50	Red	10	13	5	Green	x		x	x
Malus Formsana	184		3	30	3.1	<45	x	x	x	5	Green	x		x	x
Malus Pumila "Pendula"	185	1\1	3	70	4.2	70-75	Red	60	13	5	Yellow	3	3	6	4
Malus brevipes(Rheder)	186		5	20											
Malus ionesis "Fimbriata"	187		2	990											
Malus Marry Potter"	188		5	10											
Malus "Neville Coperman"	189		2	50											
Malus brevipes	190		5	15											
Malus "Makamik"	191		0	100											
Malus x Purpurea "Aldenhamenis"	192		3	20											
Adams	193		4	15											
Butterball	194		5	10											
Snow Magic	195		5	10											
Red jade	196		5	10	2.2	<45	Red	100	x	5	x	x		x	x
Spekappel	197	1\1	2	70	2.1	80-85	Red	50	15	2	Green	5	4	5	4
1086	198		0	100											
1132	199	1\2	4	15	3.2	85-90	Purple	70	16	5	Orange	5	4.5	4	5
1222	200	1\3	4	15	3.1	75-80	Red	90	14	5	Green	4	4	6	4
1228	201		0	100											
7105	202		1	90											

7111	203		0	100											
95013-045	204	1\1	4	10	3.2	75-80	x	x	16	4	Yellow	4	4.5	5	4
93005-017	205	3\1	4	10	3.2	60-65	Purple	85	12	5	Yellow	3	3.5	6	3
D3	206	3\1	3	40	4.1	50-55	x	x	13	4	Yellow	3	2.5	4	5
B031(Lateur)	207	1\4	3	30	3.1	50-55	x	x	11	5	Green	4	1	4	5
X	208	1\1	1	10	4.1	55-60	red	70	18	2	Orange	4	4	4	5

Diseases susceptibility scores (CGN collection ,2011)									
				Canker					
Name	Accession number	Mildew	Scab	Tree 1	Tree 2	Tree 3	Canker .avg	General d score	Remarks
Dijkmanszoet	1	2	0	2	0	0	0.67	2.67	
Renette Ekenstein	2	0	0	2	0	0	0.67	0.67	
Schneeappel	3	0	0	0	0	0	0.00	0.00	
Groninger Peppeling	5	2	2	3	0	1	1.33	5.33	
Jasappel	6	0	0	0	0	0	0.00	0.00	Still flowering
Langzoet	7	0	3	0	0	0	0.00	3.00	strong Aroma
Groninger Kroon	8	0	2	1	0	0	0.33	2.33	Acidity, biennial
Gerrie Roelof	9	2	0	0	0	0	0.00	2.00	vigour
Schellinkhouter	10	2	0	0	0	0	0.00	2.00	
Limburgse Bellefleur	11	0	0	0	0	0	0.00	0.00	
Wijnappel	12	4	0	0	0	0	0.00	4.00	Juicy
Jacob Dirk	13	0	0	0	0	0	0.00	0.00	
St.Japiksappel	14	0	0	0	0	0	0.00	0.00	
Geelzoet	15	2	0	0	1	1	0.67	2.67	
Onbek-1	16	0	2	0	0	0	0.00	2.00	
Sijden Hemdje	17	2	2	0	0	0	0.00	4.00	

Taunton Cross	18	2	0	0	0	0	0.00	2.00	Only few rotten fruits on the tree
Notarisappel	19	0	0	0	0	0	0.00	0.00	
Groninger	20	0	0	0	0	1	0.33	0.33	Fruits -red and very sweet
Paradijsappel	21	0	0	1	0	0	0.33	0.33	High yield good taste.
Zigeunerin	22	2	0	0	0	1	0.33	2.33	Poor tree appearance
Dessert	23	0	0	0	0	0	0.00	0.00	Good taste
Echtelds Zoet	24	0	0	0	0	0	0.00	0.00	Sweet and green
Eersteling	25	2	0	0	0	0	0.00	2.00	High yield .Juicy fruit
Glorie van Veendam	26	0	0	0	0	0	0.00	0.00	
Zaailing 82	27	0	0	0	0	1	0.33	0.33	Low yield
Kaneelzoet	30	0	0	?	0	0	0.00	0.00	Brown and big skin
Sevenum Striefke	31	0	0	0	0	1	0.33	0.33	Good taste
Paradijs Bedieze	32	2	0	0	0	0	0.00	2.00	Purple fruit
Zoete Winterkroon	33	0	0	0	0	0	0.00	0.00	Sweet and good taste
Jan Steen	34	0	0	0	1	0	0.33	0.33	Very good Taste
Balder	35	2	0	0	0	0	0.00	2.00	Good taste
Pomme Rosa	36	2	0	0	0	0	0.00	2.00	acidity +firmness
Herfst Zoetzuur	37	2	0	0	0	0	0.00	2.00	good ratio acid: sugar
Lunterse Pippeling	38	0	0	0	0	0	0.00	0.00	Nice appearance yellow brown
Court Pendu-1	39	0	0	0	0	0	0.00	0.00	rough skin ,sweet and good taste
Groene Kroon	40	0	0	0	x	0	0.00	0.00	Low yield, good taste
Gamerense Zure	41	0	0	0	0	0	0.00	0.00	Nice taste ,sweet.
Streepjesappel	42	0	0	0	0	1	0.33	0.33	no fruits, week trees
Schoner von Wiltshire	43	2	0	x	0	0	0.00	2.00	not good taste
Princesse Noble-2	44	2	0	0	0	0	0.00	2.00	not good taste
Grasappel	45	2	0	0	0	0	0.00	2.00	Still flowering, good taste
Present van Hien	46	0	0	0	0	0	0.00	0.00	big size nice taste
Zoete Crombach	47	0	0	0	1	0	0.33	0.33	Only few rotten fruits on the tree
Oranje Renette	48	2	0	1	0	0	0.33	2.33	

Glorie van Holland	49	2	0	0	0	0	0.00	2.00	Still flowering, good taste
Winter Gravenstein	50	2	0	1	0	1	0.67	2.67	high yield, not ready
Pomme Gilson	51	0	0	1	0	0	0.33	0.33	hard and sweet
Grote Zoete	52	0	0	0	1	0	0.33	0.33	Brown leaves ,no fruits.
Druivenzuur	53	0	2	0	0	0	0.00	2.00	Brown leaves ,no fruits.
Tonia	54	0	2	1	0	0	0.33	2.33	no fruits, week trees
Honingzoet	55	0	0	0	0	0	0.00	0.00	small apples, low yield
Lemoenappel	56	0	0	0	1	1	0.67	0.67	Sweet and big apples
Pomme Duchene	57	2	0	0	0	0	0.00	2.00	week tree
Frambozenappel	58	0	0	0	0	0	0.00	0.00	Nice appearance ,good taste
Wildling Herfstappel	59	0	0	0	0	0	0.00	0.00	low yield
Zoete Paarswang	60	0	0	0	0	0	0.00	0.00	week tree
Zure Renette	61	0	0	0	x	0	0.00	0.00	only one tree with fruits
Gronsvelder Klumpke	62	0	0	0	1	0	0.33	0.33	young tree
Rode Tulpappel	63	2	2	0	0	0	0.00	4.00	week leaves. no fruits
Yellow Vincent	64	0	2	0	0	0	0.00	2.00	
Eysdener Klumpke	65	0	0	0	0	0	0.00	0.00	only one tree with fruits
Prinses Margriet	66	1	0	1	0	0	0.33	1.33	week leaves.
Kanappel	67	0	0	0	1	0	0.33	0.33	
Lunterse Present	68	0	0	0	0	0	0.00	0.00	high yield
Belle de Lunteren	70	0	0	1	0	0	0.33	0.33	high yield
Zomerzuur	71	2	0	0	0	1	0.33	2.33	only one tree with fruits
Court Pendu-2	72	2	0	x	0	0	0.00	2.00	low yield
Renette d'Ernaut	73	2	0	0	0	0	0.00	2.00	High yield, juicy.
Peperappel	74	0	1	0	0	0	0.00	1.00	high yield
Valkappel	75	0	2	0	0	0	0.00	2.00	no fruits, week trees
Zure van Driebergen	76	0	0	0	1	0	0.33	0.33	
Rozenblaadje	77	2	0	0	0	1	0.33	2.33	high yield
Renette van Grathem	78	0	0	0	0	0	0.00	0.00	high yield

Princesse Noble-1	79	0	0	1	0	0	0.33	0.33	sour and hard fruit
April Eierappel	80	0	2	0	0	0	0.00	2.00	
Jonwin	81	2	0	0	0	0	0.00	2.00	high yield, good fruit appearance
Present van Engeland	82	0	2	0	0	1	0.33	2.33	
Zaailing de Jongh	83	2	0	0	0	0	0.00	2.00	Many fruits on the ground(early variety?)
DELGOLLUNE	84	0	0	0	0	0	0.00	0.00	high yield nice taste
Malus Golden Gem	85	0	0	0	0	0	0.00	0.00	
Malus Evereste	86	0	0	0	0	0	0.00	0.00	
Golden Hornet	87	0	0	0	0	0	0.00	0.00	
Gorgeous	88	0	0	0	0	0	0.00	0.00	
Malus Prof. Sprenger	89	0	0	0	0	0	0.00	0.00	
Grenadier	90	2	0	0	0	0	0.00	2.00	no fruits, week trees
Florina	91	2	0	0	1	0	0.33	2.33	high yield
Joseph Musch	92	0	0	1	0	0	0.33	0.33	
Pristine	93	0	0	0	0	0	0.00	0.00	no fruits, vigour.
Radoux	94	0	2	0	0	1	0.33	2.33	low yield
Reinette de Blenheim	95	0	2	0	0	0	0.00	2.00	good taste
Zaailing Leerbroek	96	0	0	0	1	1	0.67	0.67	Week leaves
Gelata	97	2	0	0	x	0	0.00	2.00	week tree
Malus Ola	98	0	0	0	0	0	0.00	0.00	
Beemsterherfst	99	2	2	0	0	0	0.00	4.00	high yield
Cwastresse Double	100	2	0	0	0	0	0.00	2.00	Sweet and good taste
S XIII 1/30	101	0	0	0	0	x	0.00	0.00	high yield
Reinette Hernaut	102	0	0	1	x	1	1.00	1.00	
RGF 4	103	2	0	0	0	x	0.00	2.00	week leaves
Woets	104	0	0	x	0	0	0.00	0.00	many bites signs on leaves
Beemstervroeg	105	0	0	1	0	0	0.33	0.33	purple leaves, no fruits
Angold	106	0	2	0	0	0	0.00	2.00	high yield
68 A	107	0	0	x	0	1	0.50	0.50	

117	108	2	0	0	0	0	0.00	2.00	
A 4	109	2	0	0	0	0	0.00	2.00	
AK 2	110	0	2	0	0	0	0.00	2.00	high yield
Colapuis	111	0	0	0	0	0	0.00	0.00	only one tree with fruits
Zoete Elisabeth	112	3	0	0	0	0	0.00	3.00	
Decio	113	0	0	0	0	0	0.00	0.00	week leaves
Durello di Forli	114	2	2	x	0	0	0.00	4.00	high yield
Lombarts Calville	117	0	2	0	0	1	0.33	2.33	week leaves
Oberrieder Glanzreinette	118	2	0	0	0	0	0.00	2.00	
President Roulin	119	4	0	0	0	0	0.00	4.00	
Reinette Clochard	120	2	0	1	1	0	0.67	2.67	
Reinette Rouge Etoilée	121	2	2	0	0	0	0.00	4.00	Not much leaves, low yield
TNR 10-8	122	0	0	1	0	0	0.33	0.33	black spots on the fruits
AK 5	123	1	2	0	0	0	0.00	3.00	many bites on the leaves
Alps Otome	124	1	0	1	0	1	0.67	1.67	high yield
KAZ 96 08-16	125	2	0	1	0	0	0.33	2.33	week leaves
KAZ 96 07-06	126	2	0	0	0	0	0.00	2.00	no fruits. Week trees
KAZ 95 05-06	127	0	0	0	0	0	0.00	0.00	no fruits, strong tree
KAZ 96 03-11	128	0	2	0	0	0	0.00	2.00	low yield, only rotten fruits
KAZ 95 18-18	129	2	0	0	1	0	0.33	2.33	low yield. Week leaves
KAZ 93 35-01	130	0	0	0	0	0	0.00	0.00	no fruits, strong tree
KAZ 96 07-04	131	0	0	0	0	0	0.00	0.00	many black spots on the leaves
KAZ 95-10-01L	132	0	0	0	0	0	0.00	0.00	many black spots on the leaves
KAZ 96 09-12	133	2	0	0	0	1	0.33	2.33	
Saltanat	134	0	1	0	0	0	0.00	1.00	Nice appearance ,good taste
CPRO 90045-133	135	2	0	0	0	0	0.00	2.00	only one tree with fruits
SIR-KEP 91-2	136	0	0	1	0	0	0.33	0.33	
DL 26	137	0	2	x	0	0	0.00	2.00	
Rembrandt	138	0	0	0	0	0	0.00	0.00	Nice appearance ,good taste, high yield

Mc Laughlin	139	0	0	0	0	0	0.00	0.00	good taste
DJ- 93-50	140	0	0	0	1	0	0.33	0.33	week leaves
Gele Zoete	141	2	2	0	0	0	0.00	4.00	Many fruits on the ground(early variety?)
Prinses Marijke	142	0	0	0	0	x	0.00	0.00	Nice taste ,sweet.
Prins Bernhard	143	3	0	x	0	x	0.00	3.00	
Prinses Irene	144	2	0	0	0	1	0.33	2.33	
Prinses Margriet	145	2	2	1	0	1	0.67	4.67	only one tree with fruits
Koningin Juliana	146	0	0	0	0	0	0.00	0.00	one tree without fruits
Prinses Beatrix	147	2	0	1	0	x	0.50	2.50	
Kaz 95 10-04F	148	0	0	0	0	x	0.00	0.00	most fruit only on the ground
Kaz 96 03-15	149	0	2	0	1	0	0.33	2.33	most fruit only on the ground
Kaz 96 08-17	150	0	0	x	1	0	0.50	0.50	Many fruits on the ground(early variety?)
Kaz 95 06-08	151	0	0	0	0	0	0.00	0.00	strong tree, fruits mainly on the ground
Kaz 96 03-05	152	0	0	0	0	0	0.00	0.00	a lot of diversity between the fruits.
Kaz 96 06-02	153	0	0	1	0	0	0.33	0.33	most fruit only on the ground
Kaz 96 03-07	154	0	2	0	0	0	0.00	2.00	most fruit only on the ground
Kaz 95 17-14	155	2	0	0	x	x	0.00	2.00	only one tree.
Kaz 96 03-11	156	0	2	0	0	x	0.00	2.00	poor leaves
Kaz 96 08-15	157	0	0	0	x	x	0.00	0.00	only one tree. Strong green leaves
85.00	158	3	2	0	0	x	0.00	5.00	high yield
A 588	159	0	2	0	0	x	0.00	2.00	high yield
FAW 12556	160	2	0	1	1	x	1.00	3.00	high yield
HL 885	161	2	0	0	0	0	0.00	2.00	hard fruits
ISF-FO 89.30.2	162	2	0	0	x	x	0.00	2.00	only one tree
Perlyna Kieva	163	0	0	0	1	x	0.50	0.50	High yield good taste.
Santaro	164	0	2	0	0	0	0.00	2.00	many bites on the leaves
Siostra Liberty	165	0	2	0	3	x	1.50	3.50	week trees
SJC 658 (01-1054)	166	0	0	0	1	0	0.33	0.33	week leaves
SJC 7441-1	167	2	2	0	0	0	0.00	4.00	

UEB 3290/1	168	2	3	0	0	x	0.00	5.00	
UEB 3322/5	169	0	0	0	0	0	0.00	0.00	good taste, big skin
UEB 3375/2	170	0	0	0	0	0	0.00	0.00	
YX 24	171	0	0	0	0	0	0.00	0.00	strong tree
CPRO 87017-37	172	2	0	0	0	0	0.00	2.00	vigour ,high yield, good taste
Deljuga	173	0	0	0	0	0	0.00	0.00	vigour ,high yield, good taste
R17T034	174	0	0	x	0	0	0.00	0.00	very good taste, high yield
88-24/13	175	0	2	0	0	0	0.00	2.00	bold tree (not many leaves, high yield
John Downie	176	0	0	0	0	0	0.00	0.00	
Hillieri	177	0	0	0	1	1	0.67	0.67	
Malus "Dolgo"	178	0	0	0	0	0	0.00	0.00	
Dolgo	179	0	0	0	0	0	0.00	0.00	strong tree.
Adirondack	180	3	0	0	0	0	0.00	3.00	
Royal Beauty	181	0	0	0	0	0	0.00	0.00	
Malus "Aldenham Purple"	182	0	0	0	0	0	0.00	0.00	vigour
Malus Coronaria	183	0	0	0	0	1	0.33	0.33	
Malus Formsana	184	0	0	0	x	x	0.00	0.00	fold leaves
Malus Pumila "Pendula"	185	0	0	0	0	1	0.33	0.33	
Malus brevipes(Rheder)	186	0	0	0	0	0	0.00	0.00	very green and strong leaves
Malus ionesis "Fimbriata"	187	0	0	x	0	0	0.00	0.00	yellow folded leaves, low yield
Malus Marry Potter"	188	0	0	0	0	0	0.00	0.00	healthy leaves
Malus "Neville Coperman"	189	0	0	1	0	0	0.33	0.33	
Malus brevipes	190	0	0	1	1	1	1.00	1.00	healthy leaves , high yield
Malus "Makamik"	191	0	0	0	0	0	0.00	0.00	vigour, yellow leaves
Malus x Purpurea "Aldenhamenis"	192	0	2	0	0	0	0.00	2.00	still flowering
Adams	193	0	0	0	0	0	0.00	0.00	o
Butterball	194	0	0	0	0	0	0.00	0.00	o
Snow Magic	195	0	0	1	0	0	0.33	0.33	
Red jade	196	0	0	0	0	0	0.00	0.00	

Spekappel	197	1	0	1	0	0	0.33	1.33	vigour, good taste
1086.00	198	0	0	0	0	0	0.00	0.00	low yield
1132.00	199	1	2	0	0	0	0.00	3.00	High yield good taste.
1222.00	200	3	0	0	0	0	0.00	3.00	good taste
1228.00	201	0	1	0	0	0	0.00	1.00	no fruits
7105.00	202	1	0	0	0	0	0.00	1.00	still flowering
7111.00	203	1	3	0	0	0	0.00	4.00	week tree, no fruits
95013-045	204	2	0	1	0	x	0.50	2.50	
93005-017	205	0	0	0	0	0	0.00	0.00	
D3	206	1	0	0	0	0	0.00	1.00	one tree looks very week
B031(Lateur)	207	2	0	0	0	0	0.00	2.00	
X	208	0	0	0	0	0	0.00	0.00	low yield, one tree without fruit

Architectural traits scores(CGN collection,2011)

Name	Accession #	Angles (1-9)	speed of growth (1-9)	New shoots Average growth (cm)	New shoots (1-9)	Bold shoots (1-9)	Stem Diameter (mm)	General score(1-9)	Remarks
Dijkmanszoet	1	8	5	15-20	7	6	36.01	6	
Renette Ekenstein	2	7	7	20-30	6	6	38.35	7	
Schneeappel	3	6	7	20-30	9	7	36.95	7	
Groninger Peppeling	5	7	7	25-30	9	7	32.43	6	Week top
Jasappel	6	6	8	30-40	4	5	40.72	6	
Langzoet	7	4	5	10	7	7	43.19	4	
Groninger Kroon	8	6	7	20	5	8	28.15	6	
Gerrie Roelof	9	9	5	15	8	8	44.4	8	
Schellinkhouter	10	8	2	10	8	6	33.74	6	Week
Limburgse Bellefleur	11	8	4	15-20	7	8	39.08	7	

Wijnappel	12	7	3	10	7	7	32.5	4	Week
Jacob Dirk	13	9	4	<10	8	8	36.08	6	
St.Japiksappel	14	9	3	20	8	7	34.07	5	
Geelzoet	15	4	3	10	5	7	32.63	4	
Onbek-1	16	9	2	<10	8	8	27.48	4	
Sijden Hemdje	17	9	6	20	9	7	37.69	9	
Taunton Cross	18	8	7	20-25	9	6	35.32	8	
Notarisappel	19	7	7	20	7	5	42.7	7	
Groninger	20	4	7	25	6	7	33.35	4	
Paradijsappel	21	7	4	40	6	4	37.95	6	
Zigeunerin	22	5	4	10	7	6	22.45	5	Young Tree
Dessert	23	9	6	20	6	7	31.79	7	
Echtelds Zoet	24	8	8	25-30	5	6	40.81	5	
Eersteling	25	9	3	10	8	8	29.76	6	
Glorie van Veendam	26	9	8	20-30	7	6	30.75	6	
Zaailing 82	27	8	6	15-20	9	8	39.78	8	
Kaneelzoet	30	5	8	30-40	5	6	42.12	6	
Sevenum Striefke	31	7	6	15	6	8	38.75	6	
Paradijs Bedieze	32	7	3	10	8	8	34.53	4	too week
Zoete Winterkroon	33	8	5	15	9	8	36.73	8	
Jan Steen	34	6	5	15	6	6	34.38	6	
Balder	35	6	6	20	7	6	33.78	6	
Pomme Rosa	36	8	5	15	7	8	39.92	8	
Herfst Zoetzuur	37	8	4	10	7	7	38.57	7	
Lunterse Pippeling	38	5	7	30	5	5	29.86	5	
Court Pendu-1	39	7	7	20-30	8	7	34.54	6	
Groene Kroon	40	6	6	15	6	6	35.46	5	
Gamerense Zure	41	7	5	15	8	7	38.15	6	
Streepjesappel	42	7	4	<10	8	6	30.19	4	

Schoner von Wiltshire	43	4	7	20	6	7	34.15	5	
Princesse Noble-2	44	5	5	15	6	8	29.48	7	
Grasappel	45	7	5	10	7	5	30.02	6	
Present van Hien	46	8	7	25	8	8	34.92	7	
Zoete Crombach	47	7	6	20	6	6	37.97	7	
Oranje Renette	48	6	8	25	9	7	37.4	7	
Glorie van Holland	49	8	5	15-20	9	8	45.64	7	
Winter Gravenstein	50	8	6	15-20	6	7	36.09	8	
Pomme Gilson	51	5	5	20	8	6	41.05	6	
Grote Zoete	52	6	3	10	7	7	26.78	5	Young Tree
Druivenzuur	53	6	3	10	6	7	30.41	5	week
Tonia	54	8	8	15-20	7	8	40.23	7	
Honingzoet	55	8	6	20	7	5	31.56	7	
Lemoenappel	56	5	8	30	7	6	41.91	5	
Pomme Duchene	57	8	4	10	5	6	25.43	5	
Frambozenappel	58	7	7	15	6	5	28.65	6	
Wildling Herfstappel	59	9	5	15	6	7	34.16	8	
Zoete Paarswang	60	8	6	20	8	8	40.09	9	
Zure Renette	61	7	6	15-20	9	9	42.73	6	
Gronsvelder Klumpke	62	7	3	10	5	5	30.08	5	week
Rode Tulpappel	63	6	7	20	8	7	29.9	7	
Yellow Vincent	64	7	5	10	8	8	33.28	7	
Eysdener Klumpke	65	9	7	30	6	8	35.06	7	
Prinses Margriet	66	6	6	20	8	5	30.92	6	still fruits
Kanappel	67	4	7	25	6	7	36.77	6	week branches
Lunterse Present	68	8	5	15	9	8	28.62	7	still fruits
Belle de Lunteren	70	9	6	15	8	7	31	8	
Zomerzuur	71	9	6	20	8	6	30.61	9	
Court Pendu-2	72	7	4	10	6	6	30.7	6	

Renette d'Ernaut	73	8	5	15	7	6	24.09	7	one tree with fruits
Peperappel	74	6	7	20	8	6	31	7	still fruits
Valkappel	75	6	7	25	6	4	32.13	5	
Zure van Driebergen	76	7	5	15	6	7	29.38	7	
Rozenblaadje	77	8	6	15	7	6	32.78	7	
Renette van Grathem	78	9	7	15	9	6	35	7	
Princesse Noble-1	79	7	8	30	7	7	34.72	6	
April Eierappel	80	6	8	25	6	6	38.48	7	
Jonwin	81	6	4	15	7	7	30.72	7	
Present van Engeland	82	7	6	30	5	4	37.35	6	
Zaailing de Jongh	83	8	7	20-25	7	5	33.27	5	
DELGOLLUNE	84	7	7	30	5	7	47.11	7	still fruits
Malus Golden Gem	85	8	4	30	7	8	37.86	6	week branches
Malus Evereste	86	8	7	25	8	7	29.22	7	still fruits
Golden Hornet	87	7	4	20	7	8	28.5	5	week
Gorgeous	88	9	4	15	5	7	29.43	6	
Malus Prof. Sprenger	89	7	6	30-40	7	7	43.8	7	
Grenadier	90	4	6	15	4	8	39.21	6	
Florina	91	6	9	35-45	8	7	50.01	6	vigour
Joseph Musch	92	7	4	15-20	7	6	31.63	5	
Pristine	93	8	6	30-40	8	6	47.46	8	
Radoux	94	5	8	30	6	7	48.44	5	
Reinette de Blenheim	95	6	7	30	7	7	28.31	6	
Zaailing Leerbroek	96	7	6	20	4	5	27.31	4	still fruits
Gelata	97	3	5	20	6	7	23.63	6	Young Tree
Malus Ola	98	7	6	20	8	7	29.94	7	
Beemsterherfst	99	8	7	15	5	7	37	8	
Cwastresse Double	100	7	5	40	7	5	37.43	6	
S XIII 1/30	101	6	6	25-30	6	8	43.98	6	

S XIII 1/30	102	6	6	10	5	5	29.3	4	
Reinette Hernaut	103	7	6	<10	6	7	26.11	5	
RGF 4	104	5	8	15	6	8	33.09	6	
Woets	105	6	7	20	6	4	41.87	5	
Beemstervroeg	106	9	5	10	8	8	34.18	9	still fruits
Angold	107	7	9	50	5	7	34.03	5	vigour
68 A	108	4	9	50	8	7	42.8	6	vigour
117	109	8	9	50	7	7	38.75	6	vigour
A 4	110	8	5	40-50	7	6	41.55	6	
AK 2	111	6	9	20-30	7	7	32.24	7	
Colapuis	112	7	9	40	6	5	39.37	5	vigour
Zoete Elisabeth	113	8	9	20-30	8	7	38.33	7	
Durello di Forli	114	5	9	10	8	8	29.45	6	week
Oberrieder Glanzreinette	117	9	5	10	9	6	30.52	8	
President Roulin	118	7	4	10	8	5	21.67	6	
Reinette Clochard	119	8	8	30-40	7	5	43.9	7	
Reinette Rouge Etoilée	120	4	7	30	8	7	37.12	6	thick branches
TNR 10-8	121	5	6	30	7	4	29.4	5	
TNR 10-8	122	6	7	20	7	6	31.69	7	
AK 5	123	7	6	15	6	6	32.46	6	
Alps Otome	124	7	4	10	8	8	26.89	6	
KAZ 96 08-16	125	7	8	25	6	6	39.83	5	
KAZ 96 07-06	126	8	6	20	7	7	28.14	6	
KAZ 95 05-06	127	9	8	40	8	7	43.17	7	
KAZ 96 03-11	128	5	6	30	7	6	35.25	6	
KAZ 95 18-18	129	4	8	30-40	7	7	33.66	5	
KAZ 93 35-01	130	3	7	30-40	5	5	44.88	5	
KAZ 96 07-04	131	4	6	20-30	7	7	38.36	6	
KAZ 95-10-01L	132	5	5	15	7	6	33.27	7	

KAZ 96 09-12	133	7	8	20	6	7	31.66	7	
Saltanat	134	8	7	15-20	6	7	39.87	8	
CPRO 90045-133	135	7	8	20-30	6	7	42.26	7	
SIR-KEP 91-2	136	7	7	20	7	8	38.9	7	still fruits
DL 26	137	7	7	15	6	5	40.14	6	still fruits
Rembrandt	138	7	8	15-20	7	8	39.03	7	still fruits
Mc Laughlin	139	9	5	15-20	8	6	44.16	7	
DJ- 93-50	140	8	6	10	4	6	30.55	6	
Gele Zoete	141	8	7	20-30	5	7	31.24	7	
Prinses Marijke	142	4	5	15	6	7	30.78	5	
Prins Bernhard	143	8	7	15	7	7	31.65	7	
Prinses Irene	144	8	5	15	6	8	31.12	8	Many fruits on the tree
Prinses Margriet	145	5	8	15-20	5	6	53.72	5	
Koningin Juliana	146	6	6	15	5	7	38.75	5	
Prinses Beatrix	147	7	8	20-30	8	7	42.76	6	
Kaz 95 10-04F	148	8	5	15	8	7	34.78	7	
Kaz 96 03-15	149	8	6	15	6	8	30.88	5	
Kaz 96 08-17	150	7	5	10	7	6	26.47	4	No balance asymmetric tree
Kaz 95 06-08	151	8	9	20	9	9	42.16	8	vigour
Kaz 96 03-05	152	8	7	20	9	8	38.3	8	
Kaz 96 06-02	153	5	7	20	7	7	43.82	6	
Kaz 96 03-07	154	8	7	15	7	7	24.45	7	
Kaz 95 17-14	155	7	4	10	6	5	36.27	5	No balance asymmetric tree
Kaz 96 03-11	156	7	4	<10	6	7	23.06	5	
Kaz 96 08-15	157	4	8	15-20	6	6	54.05	5	
85	158	7	7	20	6	6	32.93	6	
A 588	159	6	6	10	7	7	38.4	6	
FAW 12556	160	8	5	15	6	7	37	8	still fruits

HL 885	161	7	7	15	5	4	34.75	5	
ISF-FO 89.30.2	162	6	6	10	5	7	32.8	6	
Perlyna Kieva	163	7	6	10	5	7	31.52	6	
Santaro	164	7	8	15	4	5	34.25	6	
Siostra Liberty	165	8	5	10	5	6	22.2	7	
SJC 658 (01-1054)	166	9	5	15	6	8	33.46	8	
SJC 7441-1	167	7	9	30	6	7	35.76	5	
UEB 3290/1	168	5	3	<10	7	6	36.37	5	Very week
UEB 3322/5	169	7	7	15	7	8	36.3	7	Many fruits on the tree
UEB 3375/2	170	6	5	10	4	7	27.21	6	
YX 24	171	6	6	15	8	7	28.75	7	still fruits
CPRO 87017-37	172	7	9	30	7	6	40.71	6	
Deljuga	173	7	9	30-40	8	7	53.73	6	
R17T034	174	8	8	20-30	8	7	40.7	7	
88-24/13	175	4	4	15	5	6	27.14	4	
John Downie	176	7	5	15	7	8	33.49	7	
Hillieri	177	7	8	30	7	5	36.55	6	
Malus "Dolgo"	178	6	6	20	6	7	32.23	7	
Dolgo	179	7	8	20	7	8	33.46	7	
Adirondack	180	5	4	<10	7	7	22.93	5	still fruits
Royal Beauty	181	9	8	15-20	7	7	21.25	8	
Malus "Aldenham Purple"	182	8	9	30	9	8	44.98	6	vigour
Malus Coronaria	183	9	7	15	8	7	26.11	7	
Malus Formsana	184	5	3	5	5	7	29.78	4	Very week
Malus Pumila "Pendula"	185	8	8	15	7	6	35.76	5	
Malus brevipes(Rheder)	186	8	8	15	7	7	40.92	6	still fruits
Malus ionesis "Fimbriata"	187	6	6	10	8	7	32.51	6	
Malus Marry Potter"	188	8	7	20	7	7	36.7	6	
Malus "Neville Coperman"	189	7	6	15	8	7	29.8	7	

Malus brevipes	190	6	9	30-40	8	6	53.83	6	
Malus "Makamik"	191	9	8	20	8	8	44.52	7	
Malus x Purpurea "Aldenhamenis"	192	8	5	10	6	7	30.67	7	
Adams	193	8	7	10	8	8	29.51	7	
Butterball	194	8	9	40	6	7	30.36	5	
Snow Magic	195	8	8	30	7	7	34.98	6	
Red jade	196	8	6	15	6	8	30.38	7	
Spekappel	197	7	9	40	7	7	45.5	6	
1086	198	6	6	15	6	6	30.73	6	
1132	199	6	8	20-30	7	7	34.75	6	
1222	200	6	5	10	6	6	32.59	5	Very week
1228	201	5	6	15	7	5	25.21	3	Young Tree
7105	202	7	7	20	7	7	47.85	6	
7111	203	8	5	15	7	6	31.27	7	
95013-045	204	5	7	20	7	8	28.47	6	still fruits
93005-017	205	5	7	15	6	7	36.01	6	
D3	206	5	6	15	7	5	33.7	5	
B031(Lateur)	207	7	9	20-30	8	7	40.52	6	
X	208	8	6	15	8	7	23.08	8	