Internship report

Growing the CxE potato mapping population in Ethiopia

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Preface

One of the aspects to start with the MSc Plant Sciences was the opportunity for an internship with a duration of 4 months. So during my MSc-thesis I was looking for the possibilities for an internship. In the laboratory of Plant Breeding I met Biructawit Bekele Tessema. A woman from Ethiopia who was writing the proposal of her PhD-thesis.

I got to know that she would work on abiotic stress with the CxE potato mapping population. The same population I was working with during the research for my MSc-thesis. Her experiments were more focused on the field work. This is also a level on which I want to work in my future career and on which I have the most experience. Also the experiments were planned to be executed in Ethiopia.

When I asked Biructawit if she could use some extra pair of hands in order to assist her, she responded positively. However the actual drought stress experiments would be done in the months September, October, November and December. This was not fitting in my planning with regards to my studies. Fortunately Prof. Dr. Visser and Dr. Van der Linden decided to plan a control experiment with the CxE potato mapping population. This experiment could be executed during the five months of June, July, August, September and October. A period that suited me much better.

This switch made it possible for me to go to Ethiopia. Nevertheless, this was also only possible by the great effort Biructawit put in the work in order to facilitate my internship. Without this it was impossible for me to arrange such a nice guesthouse and the transport from Addis Ababa to Holetta and back. Moreover, the way she guided me through the place I would stay for five months made me feel home faster than expected. This and including me in the experiment and asking me for feedback made this internship a big success. Many thanks for that.

Other people I would like to thank are Dr. Gerard van der Linden and Prof. Dr. Richard Visser for changing their plans, the supervision, and the financial and administrative support. Many thanks also to the people of the Holetta Agricultural Research Center, especially Melaku and GebreMarcos for their advice and help during the measurements.

I wish you a pleasant reading of this report. A report that is the product of a period I will never forget.

Berend-Jan Dobma

Wageningen, October 2010.

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1. Introduction

Potatoes (*Solanum tuberosum* L.) are spread and cultivated all over the world since its introduction in 1570 in Europe. The crop is the fourth largest crop in the world after maize, rice and wheat. Tubers of the potato plant are a rich source of carbohydrates, proteins and vitamins B and C (www.potato2008.org). The tubers are produced by planting a seed tuber, which produces sprouts and consequently stems. Leaves on these stems form the canopy. At the top of a stem an inflorescence will be produced and axillary buds below the inflorescence may grow as a second-order stem as a continuation of vegetative growth. This can continue to the third, fourth and fifth-order stem (Almekinders and Struik, 1996). Depending on the genotype and the environmental conditions the level of flowering can vary (Veerman, 2003). The end of the plant life cycle is mostly marked by yellowing of the leaves. This senescence starts some time after the tuber initiation and at the end or after the flowering period (Celis-Gamboa, 2002). From the axillary buds of the stems at the below-ground level stolons are formed. The tips of the stolons start to swell, which eventually form a tuber. During the growing period of the potato plant the tuber will grow and is mature at the end of the plant life cycle. The maturity of the tuber can be determined by rubbing the skin with the thumb, without removing the skin.

Celis-Gamboa concluded in 2002, based on reviews by Ewing and Struik, 1992; O'Brien et. al., 1998; Jackson, 1999, that genotype, photoperiod, temperature, water supply, nitrogen supply and physiological age of seed tubers are the most important factors that influence the plant development and tuber formation. In relation to these factors the potato yield at the end of the plant life cycle will be influenced. Since potatoes are cultivated all over the globe, there is a large range of environmental conditions. For example this is the case with the environmental factor of photoperiod. Close to the north pole there are very long days during the months June and July, in The Netherlands days lengths are relatively long, but close to the equator days are short and have a length of 12 hours. These differences in day lengths, next to temperature, may cause differences in plant height and flowering, for example under long day conditions plants grow taller and form more flowers compared to short day conditions (Almekinders and Struik, 1996). Furthermore they describe the relation between flowering and tuber initiation. Short days cause an early flowering and an early tuber initiation of the potato plant, compared to long day conditions.

In order to have a physiological analysis of several events related to plant development and tuber formation during the life cycle of a population with a size of 250 genotypes Celis-Gamboa conducted field experiments in The Netherlands at Wageningen University and Research center in the years from 1998 till 2002. Therefore she measured the plant development of the CxE potato mapping population at three levels. At the above-ground level, traits like: emergence, plant height, number of main stems, flowering and senescence. At the stolon level measurements were done like: onset of stolon formation, number of stolons, stolon length, stolon tip swelling. At the tuber level the number of tuber incipients, tuber size distribution, tuber weight and secondary growth were measured. The growing season has long days in The Netherlands, around 16 hours (Zaban et. al., 2006) and may therefore have an effect on the development of the potato plant. Differences between the genotypes were expected to be seen since the CxE potato mapping population is a cross between *S. phureja* and *S. tuberosum*, which have different daylength requirements for tuberization (Celis-Gamboa, 2002).

CxE is a diploid potato population, which is used in many researches at the Laboratory of Plant Breeding at Wageningen UR, with regards to genetic studies in potato. *Solanum tuberosum* L. (the cultivated potato) is tetraploid and highly heterozygous. This can result in large phenotypic classes and therefore genetic studies in potato are done at the diploid level (Bradshaw and Mackay, 1994 in Celis-Gamboa, 2002). Work that is done with the CxE potato population is for example RFLP maps that were constructed on which tuber shape and flower color were mapped (Van Eck et. al., 1994, Van Eck et. al., 1993). Furthermore an AFLP map was constructed (Van Eck et. al., 1995) and an improved AFLP map was constructed by Celis-Gamboa in 2002. Based on the improved AFLP map of the CxE population, Quantitative Trait Loci (QTL) could be found that relate to the duration of the plant cycle and senescence on mainly chromosome 5 (Celis-Gamboa, 2002). Zaban et. al., 2006 did the same experiments with the CxE potato mapping population in Finland, where the longest days during the growing season have lengths of 22 hours of sun light.
In Venezuela the CxE population was grown under short day conditions. However the data from this experiment were difficult to use with regard to the ability of making comparisons with the Dutch and Finnish experiments. This was because during the experiment in Venezuela different measuring scales were applied than in The Netherlands and Finland. For example a different scale was used during the flowering time, because people were distracted by flower bud abortion (Hurtado, personal communication 2010). Hence extra data of the CxE population grown under short day conditions were demanded. Ethiopia has short day conditions since the experimental site, the Holetta Agricultural Research Center, is located 9° N. Doing a field experiment in Ethiopia, as discussed in this report, can add data to a large dataset that is already available of the CxE population. The Ethiopian, Venezuelan, Dutch and Finnish data enable the analyses of Genotype x Environment and Quantitative Trait Loci (QTL) x Environment interactions and the developmental events during the life cycle of the potato plant. A better understanding of the genetics and the developmental events can contribute to the breeding of new potato cultivars that perform well in a specific environment.
An extra feature of doing the experiment in Ethiopia was because of the presence of PhD-student Biructawit Bekele. She is working as a sandwich PhD and studies drought stress of potatoes in field experiments. With her presence in the experimental field it was possible to have supervision during the experiment of a Wageningen UR PhD student.

The next chapter deals with the methodology of the experiment. The results of the above ground measurements, like date of emergence, plant height, stem number and flowering are described in chapter three. In chapter four the results are discussed. From a personal interest a description of the Ethiopian potato cultivation is added in chapter five. This report is written as a part of an internship that took place in the Holetta Agricultural Research Center (HARC) in Holetta, which is part of the Ethiopian Institute of Agricultural Research (EIAR). The internship lasted from June 12 till October 27. A reflection on the internship can be read in chapter six.

2. Materials and Methods

2.1 Plant material

Tubers of the diploid backcross population CxE were used in the experiment. Parent C is a cross between *S. phureja* and a dihaploid of *S. tuberosum*. Parent E is derived from a cross between parent C and a backcross clone of *S. vernei* and *S. tuberosum* (references in Celis-Gamboa, 2002). Tetraploid cultivars were also included in the experiment, among them were the Dutch cultivars: Astarte, Bintje, Gloria, Granola, Karnico, Mondial, Première and Saturna. Ethiopian tetraploid cultivars in the experiment were: Awash, Belete, Bulla, Gara, Gorebella, Guassa, Gudene, Jalene, Shenkolla, and Zengena.

The seed tubers of the Ethiopian cultivars were stored in a Diffused Light Storage and because of that they had large developed sprouts. The seed tubers of the CxE population and the Dutch tetraploid cultivars were stored in a cold storage and had small white sprouts.

2.2 Location

The experiment was done at Holetta Agricultural Research Centre in Holetta, a small town 40 kilometers northwest of the Ethiopian capital city Addis Ababa. The latitude is 9° N and it is located 2390 meters above sea level. The potatoes were grown in red soil also known as Nitisoil. (www.eiar.gov.et, 2010)

Meteorological data was obtained from the meteorological service present at the research station. Table 2.1.1 shows the weather data of the months June, July, August and September 2010.

	June	July	August	September
Average minimum temperature (°C)	9,66	10,53	10,33	8,82
Average maximum temperature (°C)	23,0	21,6	20,9	21,0
Total rainfall (mm)	93,0	287,9	206,2	192,2
Average soil temperature at 20 cm (°C)	19,1	17,7	17,07	*
Average relative humidity (%)	74	72	86	*

Table 2.1.1: Weather data of the months June, July, August and September at the Holetta Agricultural Research Centre in Holetta in the year 2010. The asterisks indicate that these data were not known at the time of making this table.

2.3 Experimental design

On July 16th 2010 the 169 genotypes that are progeny of the CxE cross, two times the C and E parents, the eight Dutch tetraploid cultivars and the ten Ethiopian tetraploid cultivars were randomly planted in three complete blocks. One block consisted out of 192 plots. In each plot 6 tubers were planted, on each side of the plot a tuber of the cultivar Jalene as a border plant and 4 tubers of the genotypes that were used in the study.
In block 3 only three tubers of the genotypes CE-758 and CE-200 were planted. In the same block only 2 tubers were planted of genotypes CE-663 and CE-716. This was due to the fact that not enough seed tubers were sent.
On each side of the block a row was planted with cultivar Jalene as border plants. Picture 2.2.1. gives an impression of the lay out of the experimental field and picture 2.2.2. shows the way the experimental field was planted on July 16th 2010.

Picture 2.2.1: Detailed view of block 1 with the plots at time of planting.

Picture 2.2.2: Planting of block 1 on July 16th 2010

2.4 Crop maintenance

At the moment of planting fertilizer was applied in the ridges. This was done with diammonium Phosphate with a Nitrogen, Phosphate and Potassium ratio of respectively 18%, 46%, 0% and Urea with a Nitrogen content of 46%. Diammonium Phosphate was applied with a dosage of 195 kg/ha and Urea with a dosage of 165 kg/ha. After 39 days after planting at the second ridging urea was applied with a dosage of 82,5 kg/ha**.**
During the growth season the potatoes were sprayed 5 times with Ridomil Gold (mefenoxam and mancozeb are the active ingredients) at a rate of 2 kg/ha.
The ridges were made 2 times throughout the season until closure of the canopy.

2.5 Above ground measurements

During the growing season of the potatoes different measurements were done. They are listed below.

- Date of emergence: Date of first plants emerging in days after planting (DAP).
- Number of stems: the stems that directly emerged from the seed tuber were counted 67 DAP.
- Plant height: the plant height was measured in centimeters 9 times during the growth season, starting at two weeks after the first plants emerged and with an interval of 6 days.
- Flowering: this measurement was done by means of a scale: 0=no open flowers; 1=onset of flowering (first open flower); 2=about 50% of the flower buds open on the primary stems; 3=full bloom: flowers from primary inflorescence opened and expanded; 4=past full bloom: second and third order stems with flower buds and open flowers; 5=75% of all open flowers already drooped from 2, 3, 4th order stems; 6=last open flowers observed in 2, 3, 4th order stems; 7=end of flowering: no developing buds or open flowers.
  Data collection for this trait started after the first open flower was seen. With an interval of 2 to 3 days measurements were done with a total of 16 time points.

2.6 Data analysis

Analysis of the data was done with GenStat 11th edition. Data was checked for normality and transformed when needed. Statistical analysis was done with an ANOVA and multiple comparisons were made with the Fishers' unprotected LSD.

2.7 Study of Ethiopian potato cultivation

In order to study the Ethiopian potato cultivation, several resources were used. These were literature available in the libraries of the Ethiopian Institute of Agricultural Research, interviews with people of the National Root and Tuber Crops Research Program at Holetta Agricultural Research Centre and with Mr. Jan van de Haar, managing director of Solagrow PLC at Debre Zeit.

3. Results

3.1 Emergence date

The first plants emerged 9 days after planting and the last plants emerged 35 DAP.
A level of 26% emergence was reached at 13 DAP and after 17 days 76% of the tubers had emerged. Totally the emergence frequency was 96.78%. No data could be taken from the cultivars Astarte and Karnico, because of formation of submarine tubers (see chapter 4). In total the number of tubers that did not germinate was 80. The data collected was normally distributed, so a transformation was not needed.
Table 3.1.1 shows a summary of the data collected from the CxE progeny and its parents. The mean date of emergence was 15.62 DAP. Genotypes CE-617 and CE-618 were the first to emerge at 11.67 and 11.75 DAP respectively. The CxE genotypes that emerged the latest were: CE-715 (19.17 DAP), CE-712 (19.25 DAP), CE-11 (19.58 DAP), CE-165 (19.72 DAP), CE-763(19.92 DAP), CE-620 (20.01 DAP) and CE-115 (20.28 DAP).
An ANOVA analysis showed that there is a significant genotypic difference (P-value <0.001) in the CxE population for date of emergence. With the LSD value a multiple comparison could be executed. This value is also shown in table 3.1.1. The total multiple comparison of the CxE population is shown in appendix A.

Number of values	513
Number of observations	510
Number of missing values	3
Mean (DAP)	15.62
Standard deviation	2.30
Minimum (DAP)	11.00
Maximum (DAP)	24.33
P-value	<0.001
LSD-value	2.4104

Table 3.1.1.: Summary of the data for the date of emergence collected from the CxE population.

Data of the tetraploid cultivars is also analyzed and shown in table 3.1.2. The average date of emergence was 13.43 DAP. The P-value of <0.001 indicates that the genotypic effect for date of emergence is significant.

Number of values	51
Number of observations	51
Number of missing values	0
Mean (DAP)	13.43
Standard deviation	2.96
Minimum (DAP)	9.00
Maximum (DAP)	19.50
P-value	<0.001
LSD-value	2.624

Table 3.1.2.: Summary of the date of emergence of the tetraploid cultivars.

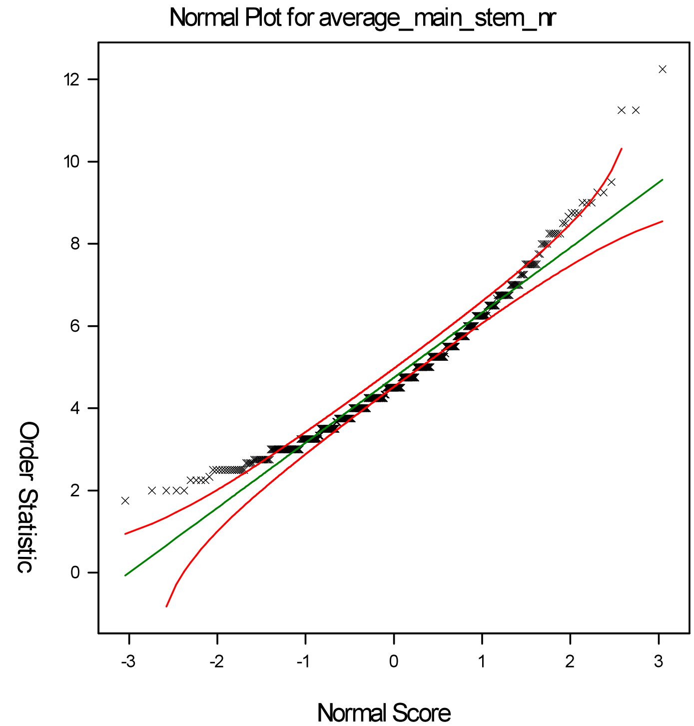
The result of the multi comparison test of the tetraploid cultivars is shown in table 3.1.3. The Ethiopian cultivars germinated earlier than the Dutch cultivars, except Awash, Gara and Belete. As mentioned before, no data was available of the two cultivars, Astarte and Karnico because of submarine tubers.

Genotype	Mean (DAP)
Gorebella	9.00[a]
Guassa	9.83[a]
Jalene	10.08[ab]
Bulla	10.25[ab]
Zengena	10.56[ab]
Gudene	12.50[bc]
Shenkolla	12.58[bc]
Saturna	13.50[cd]
Granola	13.92[cd]
Mondial	14.50[cde]
Awash	14.67[cde]
Gara	15.50[de]
Belete	15.56[de]
Desiree	15.56[de]
Gloria	16.58[e]
Bintje	16.83[e]
Premiere	16.83[e]
Astarte	*
Karnico	*

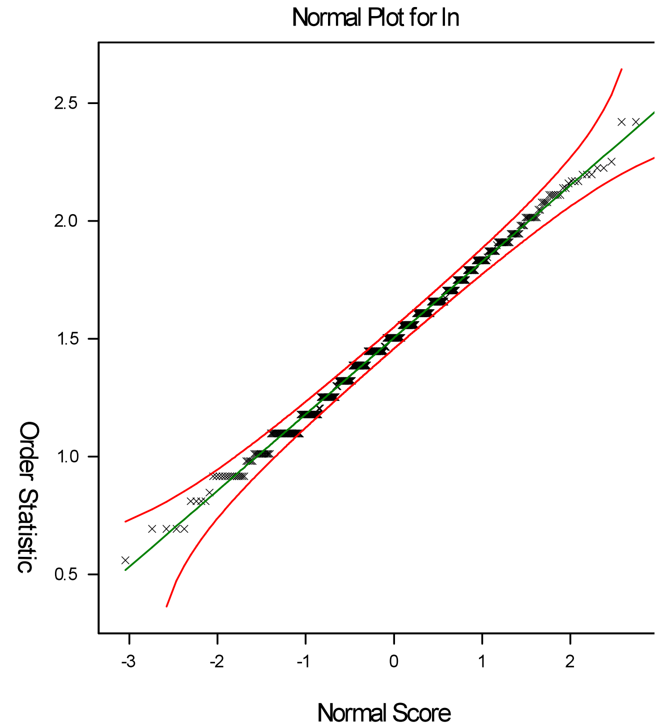
Table 3.1.3.: Multiple comparison test with the Fishers' unprotected LSD. The letters indicate the significant differences between the genotypes, based on the LSD-value of 2.624.

3.2 Stem number

The mean of stem number counted in the CxE population was 4.49 (+/- 1.38) stems per plant. The minimum amount of stems that was counted was 1.750 and the maximum number of stems was 12.250. Together with the P-value and the LSD-value, these values are summarized in table 3.1.4. The result of the multiple comparisons is in appendix B. Before doing the ANOVA, the data needed to be transformed with a natural log. Graphs 3.3.1 and 3.3.2 show the normal plot of respectively the untransformed and the natural log transformed data.



Graph: 3.3.1.: Normal plot of untransformed data of stem number of the CxE population



Graph 3.3.2.: Normal plot of transformed stem number data of the CxE population with a natural log.

Number of values	513
Number of observations	510
Number of missing values	3
Mean	4.49
Standard deviation	1.38
Minimum	1.75
Maximum	12.25
P-value	<0.001
LSD-value (natural log)	0.362

Table 3.1.4.: Results of number of stems in the CxE population. The LSD-value is derived from the natural log transformed data, because the actual multiple comparison is based on this value.

CE-genotypes 72 (2.321 stems) , 646 (2.565 stems), 756 (2.620 stems), 788 (2.743 stems), 620 (2.815 stems), 704 (2.835 stems), 738 (2.936 stems) 622 (2.948 stems), 762 (3.062 stems) and 625 (3.068 stems) formed the top ten of CE plants with the least stems.
The results of the tetraploid cultivars concerning the stem number are shown in tables 3.1.5. and 3.1.6.

Number of values	51
Number of observations	51
Number of missing values	0
Mean	5.78
Standard deviation	1.54
Minimum	2.25
Maximum	12.26
P-value	<0.001
LSD-value (natural log)	0.4030

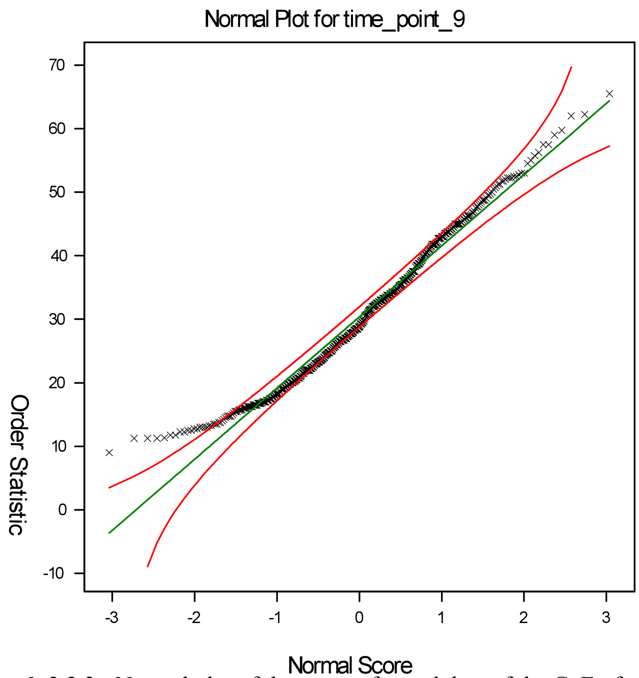
Table 3.1.5.: Summary of data from tetraploid cultivars concerning stem number

Genotype	Mean
Premiere	3.12^{a}
Bintje	3.32^{a}
Saturna	3.65^{ab}
Belete	4.13^{abc}
Zengena	4.54^{abc}
Awash	5.12^{bcd}
Desiree	5.23^{bcd}
Granola	5.30^{bcd}
Gara	5.67^{cde}
Gloria	5.81^{cde}
Mondial	5.82^{cde}
Guassa	6.82^{def}
Shenkolla	7.48^{defg}
Gorebella	8.39^{efg}
Jalene	9.23^{fgh}
Bulla	10.28^{gh}
Gudene	11.57^{h}
Astarte	*
Karnico	*

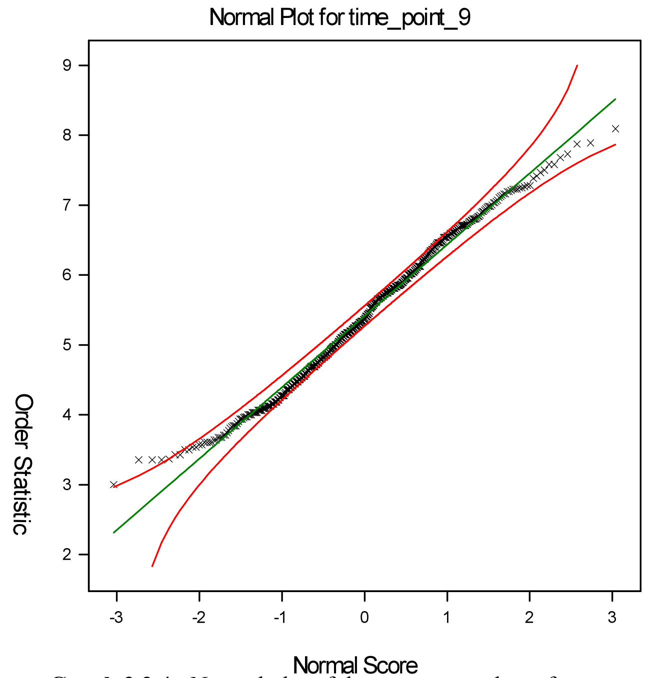
Table 3.1.6.: Multiple comparison of tetraploid cultivars concerning stem number
The letters indicate the significant differences between the genotypes, based on the LSD-value of 0.4030. The LSD-value is derived from the natural log transformed data. Since the multiple comparison is calculated with these data too.

3.3 Plant height

The average, maximum and minimum plant height per time point are shown in table 3.1.7. These figures include the CxE genotypes. The analysis was based on 510 observations, at all the nine time points. The data needed to be transformed with a square root before doing the ANOVA. Normal plots of the untransformed and the square root transformation are depicted in repectively graphs 3.3.3. and 3.3.4. The graphs show the normal plots of time point 9. Though these graphs resemble the situation of the other time points.



Graph 3.3.3.: Normal plot of the untransformed data of the CxE of the CxE population for plant height at time point 9



Graph 3.3.4.: Normal plot of the square root data of the CxE population for plant height at time point 9

Time point	1	2	3	4	5	6	7	8	9
DAP	26	32	38	44	50	56	62	68	74
Average plant height	7.38[a]	11.43[b]	15.79[c]	20.54[d]	24.74[e]	26.87[f]	29.18[g]	29.76[h]	29.25[i]
Standard deviation	0.229	0.261	0.362	0.537	0.627	0.841	0.964	0.970	1.051
Maximum plant height	15.25	23.00	31.25	44.76	53.74	61.24	68.38	65.50	65.50
Minimum plant height	1.83	4.00	5.25	5.83	10.00	9.25	10.00	11.12	9.00

Table 3.1.7: Average, standard deviation, maximum and minimum plant height of the CxE genotypes used in the experiment at each time point.

Time point	1	2	3	4	5	6	7	8	9
DAP	26	32	38	44	50	56	62	68	74
Average plant height	11.76[a]	16.73[b]	22.17[c]	28.83[d]	34.33[e]	37.10[f]	39.63[g]	40.50[h]	39.96[i]
Standard deviation	0.70	0.77	0.91	1.08	1.30	1.37	1.55	1.67	1.67
Maximum plant height	27.88	34.50	44.50	52.50	62.25	65.37	71.25	81.25	81.50
Minimum plant height	2.37	4.50	7.50	10.75	12.50	13.50	12.50	14.50	11.50

Table 3.1.8: Average, standard deviation, maximum and minimum plant height of the tetraploid cultivars used in the experiment at each time point. The letters indicate the significant differences between the time points. The LSD-value of the square root transformed data was, 0,04105.

Table 3.1.8 shows an overview of the plant height of all the tetraploid cultivars used in this experiment. The analysis was based on 51 observations. At every time point a large range between the maximum and minimum plant height can be seen. For example at time point 9 the maximum plant height is 81.50 cm and the minimum time point is 11.50 cm.

Table 3.1.9. shows the result of a multiple comparison of plant height of tetraploid cultivars in centimeters at time point 9.

Cultivar	Mean height (cm)
Premiere	15,15[a]
Gloria	25,00[b]
Granola	25,12[bc]
Bintje	27,76[bc]
Desiree	28,69[bc]
Awash	30,09[bc]
Saturna	33,54[bc]
Mondial	36,14[bcd]
Shenkolla	36,89[cd]
Bulla	48,19[de]
Gorebella	52,40[e]
Guassa	54,66[e]
Belete	54,91[e]
Gudene	54,91[e]
Gara	57,03[e]
Jalene	59,58[e]
Zengena	62,52[e]
Astarte	*
Karnico	*

Table 3.1.9: Average plant height of the tetraploid cultivars at time point 9. The letters indicate the significant differences between the genotypes, based on the LSD-value of 0,737. This LSD-value is derived from the analysis with the square root transformed data.

3.4 Flowering

First open flowers appeared on the 38th day after planting in both the CxE population and the tetraploid cultivars. From this moment the scoring of the flowering started. Overall the flowering was scored at 17 time points, with an interval of 2 to 3 days. From these data, a descriptive statistical analysis has been done, based on either 1992 CxE plants or 200 plants of the tetraploid cultivars. The diagrams of the CxE population and the tetraploid cultivars are depicted in appendix C. These diagrams show the progress of flowering by means of the percentages of plants that are in a certain flowering stage according to the used scale at time point 1 (38 DAP), time point 8 (54 DAP) and time point 16 (74 DAP).

At 38 DAP 0.15% of the plants of the CxE population formed the first open flower, 50.98% and 48.87% formed respectively flower buds and no flower buds at all. In 87.06% of the tetraploid cultivars no flower buds were present, where 11.94% of the plants formed flower buds and 1.00% had the first open flower.
At 54 DAP (time point 8) 36.32% of the CxE plants did not form any flower buds, compared to 31.46% of the plants which were in full bloom. The percentage of plants of which half of the flowers were opened was 13.78%, but at the same time 12.02% already past full bloom. Regarding the tetraploid potatoes 62.00% of the measureable plants did not form any flower

buds, 16.00% had no open flower buds yet, 8.50% had their first open flower, and 7.00% was in full bloom.
Finally at 74 DAP, 51.96% of the CxE population ended flowering. Still 36.30% of the plants did not have formed flower buds at all. 4.00% was still flowering, but passed the stage of being in full bloom. At 74 DAP 37.00% of the tetraploid plants ended their flowering. 58.50% of this group did not form any flower buds during the growing season.

4. Discussion

During the planting of the experiment the seed tubers had large sprouts. This indicated that they were physiologically aged. Another indication of old tubers was the formation of submarine tubers of the tetraploid cultivars Astarte and Karnico in all the three blocks. Submarine tubers are seed tubers that directly form small tubers instead of sprouts. Pictures 3.2.1 and 3.2.2 show the submarine tubers of Astarte and Karnico respectively.

Picture 3.2.1: Submarine seed tuber of Astarte

Picture 3.2.2: Submarine tuber of Karnico

Measuring the date of emergence also resulted in 80 missing values. This was due to rotting or the physiological age of the tubers. The rotting was caused by the heavy rainfall during the growing season, which resulted in water lodging. The high physiological age caused an absence of sprouts and therefore those tubers did not germinate.
However the tubers that did germinate formed well-developed plants. Moreover, Celis-Gamboa reported in 2002 that physiologically aged tubers do not influence the timing of the occurrence of other events in the life cycle. So with regard to the experiment in Ethiopia it is likely that the results are not influenced by the age of the seed tubers, but by the genotypic differences and environmental factors present at the experimental location.

With respect to the stem numbers, one must take into account the fact that the seed tubers that were used in this experiment, had different sizes. In addition the Ethiopian cultivars were stored differently compared to the CxE population and the Dutch cultivars. This may have influenced the results. For example the seed tubers of the CxE population had relatively smaller tubers compared to the Dutch and Ethiopian tetraploid cultivars. Smaller tubers have less eyes per weighing unit compared to bigger seed tubers (Veerman, 2003). The Dutch and Ethiopian cultivars had a bigger size of seed tubers and therefore more eyes that could form a stem. According to Veerman, 2003 the stems that grow from a bigger sized tuber grow faster and easier when the growing conditions have somewhat lower temperatures and higher rainfall.
Moreover, the storage method of the Ethiopian cultivars was different than the CxE seed tubers and the Dutch tetraploid cultivars. See section 2.1 of chapter 2 and section 5.1 in chapter 5. This may have had an effect on breaking the dormancy and the formation of the sprouts. Tubers stored in a Diffused Light Storage formed strong green sprouts at all the eyes, that do not break easily during transport and planting. The seed tubers of the Dutch cultivars and CxE population had

long white sprouts which could break easily during planting. Moreover, these seed tubers were shipped from Wageningen (The Netherlands) to Holetta (Ethiopia).
As described in section 3.3 of chapter 3 it can be seen in table 3.1.9. that the Ethiopian cultivars form a group with the tallest cultivars, where the Dutch cultivars form the groups with the smallest plants at time point 9. This large difference is caused by the indeterminate growth habit of the Ethiopian cultivars. The canopy keeps growing by forming 2nd, 3rd and 4th order stems throughout the season. The Dutch cultivars form a canopy and stop growing (Jan van de Haar, personal communication, 2010). An indeterminate growth habit relates to a longer life cycle, compared to the determinate growth habit (Celis-Gamboa, 2002; Veerman, 2003).
Weather conditions were favorable for late blight infections. Compared to the Ethiopian cultivars, the CxE population and the Dutch tetraploid cultivars were highly susceptible. This is one of the reasons why Jan van de Haar tries to avoid to grow a potato crop in the rain season (see also chapter 5). Spraying two times with Ridomil was not sufficient and the experiment needed to be sprayed 5 times. However this was hardly sufficient and made it difficult to assess senescence because some plants were heavily damaged as a result of the infection. A possibility of the lower susceptibility of late blight could be explained by the indeterminate growth habit of the Ethiopian cultivars. In the surrounding multiplication fields at HARC it was seen that lower leaves of the Ethiopian cultivars were infected with *Phytophthora infestans*, but the upper parts of the canopy kept growing. In addition with two sprays of Ridomil, the infection could be stopped.

Flowering of the CxE genotypes started 38 DAP in Ethiopia compared to 36 DAP in Holland (Celis-Gamboa, 2002). Data of flowering of the Dutch experiment were not available, so this comparison is not statistically analyzed. For further comparisons the thermal days, day lengths, rainfall and radiation need to be taken into account. For example a clouded day in The Netherlands is different than a clouded day in Ethiopia, because of the different day lengths and radiation of the sunlight, which is much stronger in Ethiopia.
As mentioned in section 3.4 of chapter 3, 58.50% of the tetraploid cultivars did not have formed any flowers at 74 DAP. The percentage of flowering plants is derived from the Ethiopian cultivars only. According to Veerman, 2003 flowering is determined by cultivar, day length and temperature. In Holland the days are long enough to induce flowering. The day lengths around the equator are probably too short for the Dutch cultivars to flower. Also high temperatures are able to influence the flowering. On one hand it can induce abundant flowering of cultivars that normally not flower under the Dutch cultivars, on the other hand flowers drop earlier and berries are not formed (Veerman, 2003). In the case of this experiment the average maximum temperature was between the 21°C and 23°C and berries were formed in some cases.

5. Study of Ethiopian potato cultivation

5.1 Introduction

The total area of Ethiopia is 1,104,300 km^2. 10.01% of that is used for arable farming. Ethiopia's economy depends largely on agriculture. 85% of the people are working in agriculture and there is a contribution to the countries Gross Domestic Production (GDP) of 45% (CIA-The World Factbook, November 9 2010).
According to references in Gebremehdin Woldegiorgis et. al., 2008 around 70% of the farmland in Ethiopia is suitable for potato cultivation. However it is also mentioned that the rate of potato production and productivity is still low.
The National Roots and Tubers Research Program that has started in 1975 was coordinated in Holetta Agricultural Research Centre until three years ago. The research on the potato crop was part of the program. This program resulted in the introduction of improved production practices and germplasm of potato to the farmers. Now the research of root and tuber crops is part of a wider program on horticultural crops, coordinated elsewhere, after an organizational change of the institutes by the Ethiopian government. The country's potato research is still done in Holetta.

Growing area
At this moment around 160,000 to 170,000 hectares of potatoes is cultivated. This is after a large increase since the 1970's. At that time 30,000 hectares was planted and this number was increased in the 1980's up to 50,000 hectares. The growing areas of potatoes in Ethiopia are indicated in figure 5.1.1.
This increase is due to several factors, such as:

- The need for a more productive crop, to meet the growing need for food. Potato is considered to solve part of the problems with food shortage and poverty.
- The need for a cash crop in order to increase the farmers' incomes.
- The image of potato as poor man's food has changed, for example because of an increasing awareness of the diversity in use of the tubers.
- The rise of the price of pulse crops caused an increase in the use of potatoes as a substitute in several dishes.
- And finally the farmers' availability of improved technologies increased the acreage of potato cultivation.

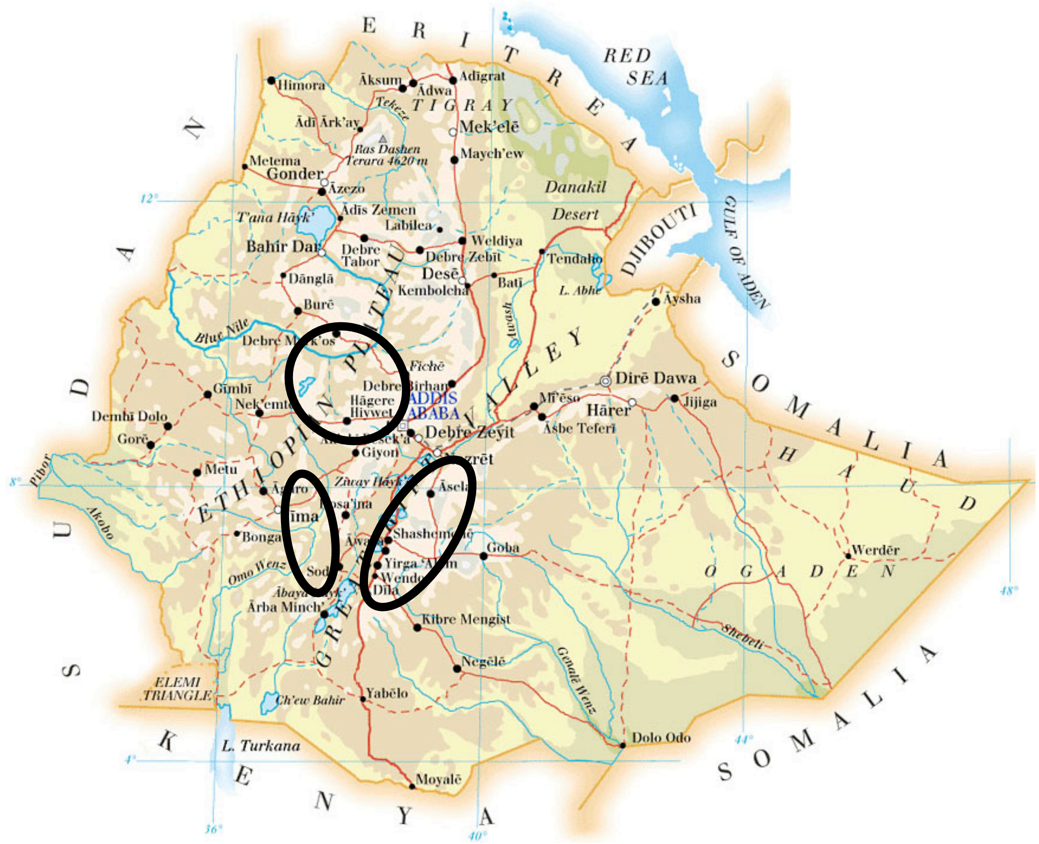


Figure 5.1.1: Map of Ethiopia with the main growing areas of potatoes that are indicated by the black ovals.

Use of the potato tubers
Most potatoes are used for boiling and therefore the use is relatively conservative. But it is also seen that in traditional stews the potato is replacing the pulse crops, like peas, lentils and beans in these dishes. In urban areas the use of potatoes has increased because of the increased consumption of crisps, French fries, salads and mixture preparations with other vegetables.

5.2 Agronomy of the potato production

Position of potatoes on the farm
Depending on the region potatoes occupied 7 to 13% of the farmland during the long rain season (*meher*) season in 2006. The rest of the farm is planted with crops like teff, barley, wheat, linseed and pulse crops.
A crop rotation with a high percentage of potato production can cause problems with the soil structure, soil borne diseases and soil fertility. However for some regions in Ethiopia there are still opportunities to increase the percentage of potato production on the farm, without above mentioned problems (Gildemacher et. al., 2009a).
A farm in the highlands of Ethiopia has a size of 0.5 ha up to 2 hectares. The farmers grow around 0.25 hectares of ware potatoes on their farms. In areas around Jeldu the area of potatoes grown by a farmer can go up to 2 hectares. These farmers grow seed potatoes. By means of the added value of the seed potatoes they are able to rent extra land for the seed production.

Growing season
In Ethiopia potatoes can be grown throughout the year, because of the possibility of different planting times. Two major production seasons of potato are the *belg* season (January till June) and the *meher* (June till October).
In the *belg* season the potatoes are planted in January and are rain fed in this short rain season. In the end of this season irrigation is used to supply enough water. Late blight pressure is less present and prices of ware potato are higher compared to the long rain season (*meher*).
The *meher* season, also known as the long rain season, is the important planting time for the farmers in the northwestern parts of Ethiopia. In this season there is a large availability of water by means of rainfall and hence a high production of potato is possible. However in this season there is also a high disease pressure of late blight. This growing season is important, because the potatoes can be harvested before the cereals are ready for harvest in the highland areas. Harvesting potatoes before the cereal crops enables the farmers to fill the gap in their food supply, when the stock of cereals is empty and the new cereal crop can not be harvested yet.
Also some farmers plant potatoes in the period from October till January. By doing this they can make use of the residual moist of the main rain season and are able to harvest from January onwards. Also in this so-called off season irrigation is needed.
Figure 5.1.2 gives a graphical overview of the potato production seasons in Ethiopia.

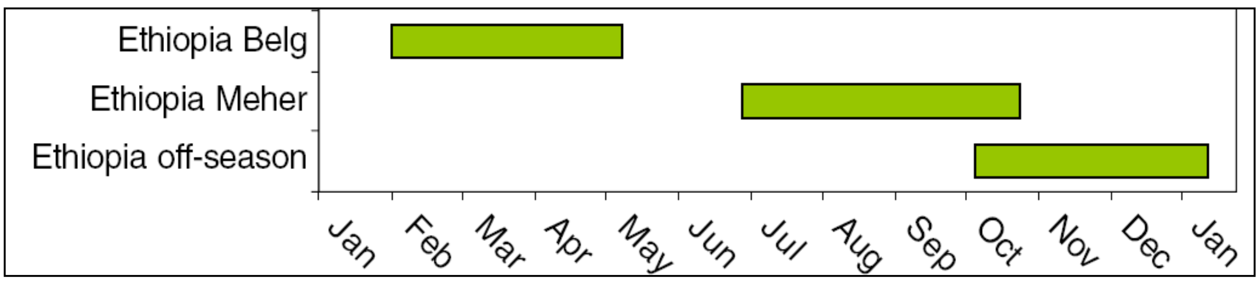


Figure 5.1.2: Graphical overview of the potato production seasons in Ethiopia. (figure taken from Gildemacher et. al., 2009a)

Field preparation and planting
To prepare the field the farmers will plow the field 2 to 3 times with a pair of oxen. Picture 5.2.1 shows an example of a farmer plowing his field with a pair of oxen around Debre Zeit.

Picture 5.2.1: A farmer plowing his field with a pair of oxen around
Debre Zeit. Plowing 2 to 3 times results in a field that is suitable for planting potatoes.

After the plowing the potatoes can be planted. The Ethiopian Institute for Agricultural Research recommends the farmers to plant the potatoes with 75cm between the rows and 30cm within the rows. When the planting is finished the ridging is done by hand.

Seed potato production

In Ethiopia, there is almost no certified seed production or distribution for potato. Therefore there is a shortage of quality seed tubers. Most seed tubers are unmarketable small size tubers derived from ware potato production (Gildemacher et. al., 2009b). This results in a degeneration of the potato crop over time.

The degeneration of the potato crop is caused by the presence of viruses, bacteria and other pathogens that are present in or on the seed tubers. When these are planted the yield of the next crop will be lower, because of a build up of diseases. Several references indicate that potato virus Y (PVY) and Potato Leaf Roll Virus (PLRV) are the viruses mostly present in potato fields and hence have the largest economical impact on the potato production (Bekele et. al., 1995, cited in Gebremedhin et. al., 2008, Gildemacher et. al., 2009b and Fuglie, 2007).

There are two seed supply systems in Ethiopia. A formal seed system in which two cooperatives are recognized as official seed producers. The other system is the informal seed system where there is a large exchange among farmers of seed tubers that were selected on the farm. The Ethiopian Agricultural Research Institute (EARI) is trying to improve the seed tubers, by means of supplying relatively clean pre-basic seed that farmers can multiply. Also training is given to improve the selection skills in order to recognize the infected plants, which farmers can rogue out (negative selection) or by placing a stick next to the healthy plants (positive selection).

In some regions of Ethiopia farmers purchase seed tubers from other areas than their own. This is because of the fast build up of diseases in their region. Also the tubers that are freshly harvested are still dormant and if the farmer wants to plant another potato crop the same year it might give problems with the germination at planting time. So there is an exchange of seed tubers between farmers from different regions. However some regions don't exchange seed tubers, but are only a seed source for other regions.

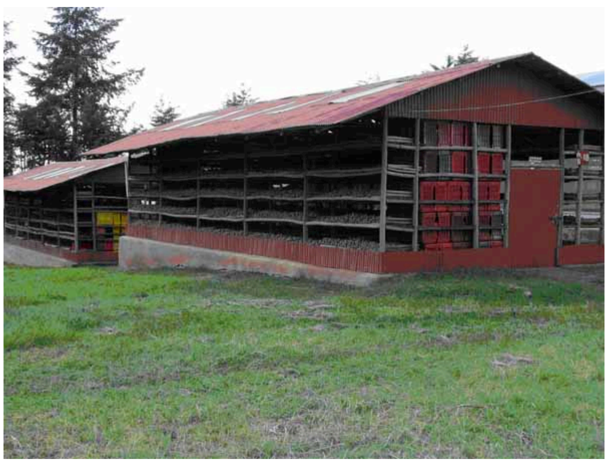
Despite the fact that there is an exchange of seed tubers among the farmers and input from the EIAR, a proper seed system with the required certification and quality standards is still lacking.

A new commercial source of seed tubers for the farmers is Solagrow PLC. This is a recently started company in Ethiopia that has the goal to establish commercial seed potato production. They receive E-class certified seed tubers of HZPC varieties, produced in the Netherlands. They are multiplying the potatoes another two times before selling it to the farmers. From each seed lot a sample is taken and tested in their newly built laboratory. With diagnostic tests the presence of pathogens can be checked. If there are no pathogens found the seed lot is approved to be sold. Because there is no official certification system this approval will have the so-called "Solagrow Quality Standard" (personal communication with Jan van de Haar, August 2010).

In the highlands of Ethiopia there is a lower presence of pathogens and vectors like aphids and are therefore good sources of seeds. For the future this type of regions are good opportunities to be a source for seed potatoes. For example Solagrow PLC has bought fields in the area between Holetta and Ambo to start up larger scale seed potato production, which is also an example and training center for neighboring farmers. If this succeeds the region can be a source of high quality seed tubers.

Storage methods of seed potatoes
As described above, freshly harvested tubers are still dormant and cannot be used as seed potatoes for the following crop cycle. As a result of that the seed tubers need to be stored until they are ready for planting. That means the tubers have lost their dormancy and have developed sprouts.
Common practice for storing the potatoes is to leave them in the soil until use. This way of storing results in a larger presence of tuber borne diseases and a physiological age of the tuber that is not optimal. Gildemacher et. al., 2009b reports that 47% of the interviewed farmers store their seeds with this method.

A more proper way of storing the seed potatoes is to put them in a Diffused Light Storage (DLS). This is a shed where the seed tubers can be stored and handled with care and inspected frequently. Storing the seed potatoes in a DLS results in tubers with good strong sprouts and a good vigor. Planting tubers from DLS allows a rapid and uniform germination. Picture 5.2.2 shows an example of a DLS.



Picture 5.2.2: Diffused Light Storages at Holetta Agricultural Research Centre. The open structure allows the potatoes to break their dormancy and the light causes strong short sprouts.

Only 5% of the farmers in the Gildemacher et. al., 2009b survey uses this type of storage. 18% of the respondents were storing the seed tubers in a light place in their house, which has the same result as storing in a DLS.

Crop maintenance
Based on research done by the EIAR, farmers should apply several practices during the growing season to be able to harvest a good yield at the end of the season.
In general it is recommended to apply 165 kg/ha N and 90 kg/ha P_2O_5 fertilizers. Ridging should be done to cover the potatoes with sufficient soil. This can prevent the formation of green tubers and damage by the potato tuber moth. The ridge should be at least 50 cm wide and 24 cm high. Between the time of emergence and the closure of the canopy ridging should be done at least 2 to 3 times.
Spraying against Late Blight should be done 1 to 2 times in the beginning of the season with Ridomil at a rate of 2 kg/ha. A higher frequency of spraying is not possible, because farmers can not afford to buy more chemicals.

Most of the farmers that are joining participatory groups with the goal to improve their potato cultivation, are using these cultivation practices. Still a lot of farmers are not joining these groups and don't use the improved techniques. This group of farmers consider potatoes as a food source to fill the gap when the stock of cereals is finished and the new cereals are not harvested yet. Also animal products like milk and meat are more rewarded in Ethiopia, so potatoes are of minor importance for these farmers. When they grow potatoes they don't apply the best practices but are using poor seed that was not stored in a DLS, they are not removing weeds, are not applying fertilizers and fungicides and grow the potatoes without ridging. This results in very low yields of about 3 tons/hectare, where the national average yield is between the 20 and 27 tons per hectare.

Harvesting
Harvesting is either done in one time, or in little amounts when needed. A complete harvest of the field is done when the prices are good and the farmer does not expect the price to increase more. The period of harvesting little (piece meal) amounts can take up till the next crop is ready for harvest. E.g. when the farmers need potatoes to prepare a meal, they will harvest the amount needed for the meal. The rest of the product stays in the soil as a way of storage.

Storage
Ware potatoes are mainly stored in the field, in the same way like the seed potatoes as described above. The potatoes are harvested in amounts that are needed by the farmers' family to satisfy their consumption. This way of storage is also done to avoid low market prices at the time of harvest, when there is a peak in the supply. In the relatively cool highlands the potatoes can be stored like this for four months. However rainfall can cause rotting and the tubers are continuously exposed to potato tuber moth.
Other common practices to store the product are making a pile on the floor in a room, put the potatoes between a space under the floor or in a pit in the ground. In cooler areas it is possible to store the potatoes like this for 2 to 3 months. However high levels of weight and quality loss are caused by respiration of the tubers.
These difficulties with potato storage force the farmer to sell the product shortly after harvest for lower prices, at the peak of the production. Better storage facilities should provide the farmer the ability to store the potatoes and wait for an improved market situation.

It is estimated that after harvest 30 to 50% of the produce is lost during storage. To prevent this huge loss the Holetta Agricultural Research Centre recommends to use a special ware potato storage facility. Picture 5.2.3 shows the type of storage that can be easily build from material available in the area of the farm. This type of storage has natural ventilation. During the night, when the temperatures are lower, the openings can be opened in order to cool down the stack of potatoes inside. Experiments at Holetta showed a storage period of at least four months with losses between 5 to 17,5%. The implementation of this storage type is at this moment low.

Picture 5.2.3: Example of a ware potato storage at Holetta Agricultural Research Center. The wide roof provides shade on the walls, so the inside temperature stays low.

To improve the quality of the stored potatoes Solagrow PLC initiated a collecting centre for potatoes that are used to make French fries. Until now farmers were supplying the hotels and restaurants with potatoes that were derived from field storage. This resulted in a product with a low quality because in contained tubers with black hearts. With this collecting centre Jan van de Haar wants to increase the awareness of quality among the producers and buyers. Also a more stable supply is guaranteed.

Marketing
Farmers can put their ware potatoes on the market in different ways. In the central highlands the most common strategies are: selling at the farm gate before harvest, selling at the local market and selling in other towns.
Selling at the farm gate before harvest means a broker or trader will visit the farm before the potatoes are harvested. If the farmer and the buyer agree about the price, the broker or trader takes care of the harvest. This means that the broker or trader takes responsibility for the labor force, packaging material and transport to the market. With this method the product reaches the market quickly without losing much of its quality.
Farmers have also the possibility to harvest part of their crop and take it to a nearby market with a pack animal. Prices are fluctuating very much, depending on the supply. The product can be sold to consumers, brokers or wholesalers.
Some farmers have trading as a part-time job. This means that they will take their own potatoes and those of neighboring farmers to the markets in other towns. Here the prices are good and the farmer-trader can get a good margin. However these type of farmers face fierce competition from the wholesalers. The wholesalers have lower marketing costs because of the larger volumes they trade and the more stable supply they can deliver to the retailers.

Main pathogens and pests
In Ethiopia late blight (*Phytophthora infestans*), bacterial wilt (*Ralstonia solancearum*) and viruses, with Potato Leaf Roll Virus (PLRV) and Potato Virus Y (PVY) as the most important, are the pathogens that reduce the potato production.
Late blight is occurring throughout the whole year, but is the most severe in the main rain season (*meher*). Therefore farmers shifted their production towards the short rain season (*belg*) and the off season. However irrigation is needed in order to have a sufficient water supply. By not

growing the crop in the main rain season the farmers miss the opportunity to grow a high productive crop. Since there is enough rain fall as water supply in the *meher* season.
Viruses and bacterial wilt is mostly spread by means of contaminated seed tubers. A good quality system including sanitation regulations and measurements is needed to prevent further spreading and enhance a good potato production.
Insects that can damage the potato crop are the potato tuber moth (*Phthorimaea operculella*), red ants (*Dorylus spp.*), cutworms (*Agrotis* spp. and *Euxoa* spp.), potato epilachna (*Epilachna hirta*), metallic leaf beetle (*Lagria vilosa*), potato aphid (*Macrosiphum euphorbiae*) and the green peach aphid (*Myzus persicae*).
From all the above mentioned insects the potato tuber moth is the most important insect. Its larvae are eating the stems, mine the leaves or tunnel through the tubers. Once the tubers are stored the larvae can spread through the whole stock and damages the product. This results in tubers that are unsuitable for further use. In this way seed tubers can be infected as well. During storage the population can build up, with the consequence that at planting time a large amount of infected tubers are brought back to the field.
Red ants result in yield loss, by means of scraping phloem tissues off the roots and destroying root hairs. Tubers can be damaged by the ants because they make holes and eat from the starch. The damaged tubers can not be sold anymore.
Aphids give sucking or chewing damage, but most important they are transmitting viruses like the earlier mentioned PVY and PLRV.

5.3 Potato breeding in Ethiopia

Breeding goals
The three most important breeding goals of the breeding program are: selecting varieties with high yields, wide adaptation and resistance to late blight.
Also traits like tuber shape, storability, cooking quality and taste are evaluated during the selection.
High yields are needed to increase the production and the productivity of potatoes in the country and in the field. In this way the farmers' household can be fed, but it is also able to sell the surplus of the production and hence the household can generate an extra income.
Ethiopia has different climates, because the land is situated at different heights above sea level. To be able to grow a variety throughout the country a widely adapted cultivar is preferred.
Late blight (*Phytophthora infestans*) is considered to be the most severe pathogen for potato in the country. Selection of new cultivars is focused on a durable horizontal resistance to late blight. This is done to give the farmers the ability to have a good yield and to produce potatoes in the main production season, the *meher* season.

Target area/group(s)
The main selection is done at the research stations, where screening will be focused on the performance on the farms. At a later stage in the selection process farmers are also included. By including the farmers in the selection, not only information about the performance of the new clones at the farm will be gathered, but also the farmers can give information about the marketability of the selected clones.
At this moment selection has started for varieties that are suitable for processing, like French Fries and crisps.

Who are the breeders?
The Ethiopian Agricultural Research Institute is responsible for the potato breeding in Ethiopia. They receive their germplasm from the International Potato Centre (CIP) in Peru. Also the higher educational institutes are involved in the different aspects of potato cultivation. It might occur that they have their own breeding research or are doing research on the agronomical practices. In addition to that, the company Solagrow PLC in Debre Zeit is starting up its activities to introduce potato varieties in Ethiopia that are bred by the Dutch company HZPC. This company is now active for three years.

Breeding techniques/methods
In the first year the germplasm is grown in a quarantine field and evaluated on quarantine diseases and resistance to late blight.
In the second year the clones are grown in a field with a high pressure of late blight by means of growing highly susceptible cultivars as border plants.
Also in these stages the visual appearance of the plants is evaluated and taken into consideration during selection.
In the following two years multi location trials are conducted. Yield stability and resistance to late blight are the most important traits during these evaluations. On average 10 to 20% are selected to go to the next stage of selection.
The clones that had a good performance in the previous two years will be grown in the pre-national variety trial (PNVT). This means an one season evaluation in three different environments.
In the national variety trial (NVT) the best clones from the PNVT are tested in 8 different locations for 2 years. The goal is, as mentioned earlier, to develop a variety that has a stable yield in the different environments present in Ethiopia.
Before the varieties of Solagrow are put on the national list they are tested in an adaptation trial, to see if they are suitable for growing in Ethiopia. In this trial the varieties of Solagrow, the Ethiopian varieties are grown in different environments 2 years in the main season and off-season. If the varieties of Solagrow are performing equally to the Ethiopian standard varieties they can continue with the verification trial.
The verification trial is a trial were the clones coming from the NVT and the adaptation trials will be tested by the releasing committee, which is responsible for the national variety list.

Release and distribution of the new cultivars
After the verification trial the new cultivars will be put on the national list. Farmers will be introduced to the new varieties by means of demonstration fields organized by EIAR. If the farmers like the new varieties, they can subscribe for seed tubers and grow them on their farms the season after. These seed tubers will be distributed by EIAR.

Breeders' rights
Farmers don't pay for the seeds they obtain from EIAR. This means there are no revenues for the seed potatoes, after selecting new varieties and multiplication. Because EIAR is a governmental institute it will receive its income from the government.
Specialized seed growers can receive their pre-basic material for free and sell the seeds after. When they do this the seed growers have to return the same amount of seed tubers as they

received from EIAR after harvest. These seeds will be redistributed to other farmers the year after.
Jan van der Haar of Solagrow is not afraid for farmer saved seeds. Good quality makes farmers renew their seeds regularly. As the farmers are not able to keep their seeds free of viruses and bacteria. So after some seasons the farmers want to buy seeds from Solagrow PLC again.

5.4 Future perspectives

Certification and seed distribution system
As mentioned earlier there is no certification system for seed potatoes. It is said that such a system is on its way. The standards are now known and the application will be similar to the different systems available, like the Dutch, Asian and Kenyan systems.

Aeroponics
In the year of 2010 the Holetta Agricultural Research Center started with the production of mini tubers by means of aeroponics. This technique is used to have clean seeds at a high multiplication rate.
Aeroponics is a technique were media like soil or water are not used, but the roots will hang in a fog of water and nutrient solution instead. By doing this it is possible to grow pre-basic seeds free of viruses and bacteria. Picture 5.2.4 shows the greenhouse with the plants growing in the aeroponics.

Picture 5.2.4: greenhouse with potato plants in aeroponics. The greenhouse is covered with a net to prevent aphids to enter. The plants grow in Styrofoam boxes where inside a fog of water and nutrient solution is spread, which will be taken up by the roots.

Biotechnology
At this moment the use of biotechnology is only done by means of cell tissue culture in order to have a rapid and fast multiplication of potato plants. There is no need for other molecular techniques yet.

Introduction of processing varieties by Solagrow PLC in order to create added value.
Jan van der Haar indicated that his company has recently started and he is very happy to have already three varieties on the Ethiopian National list. In the meanwhile he has multiplications of these varieties in order to have enough product to sell. Next to the selling of the seed potatoes he

is researching the farming practices for the rotation crops that are grown on the farms. By doing this he can give advise how to implement potatoes in the crop rotation and improve the overall performance of the farms.
Next to the three varieties that are already on the list, Jan van de Haar tries to get more varieties on the Ethiopian National list. These varieties are more suitable to process into products like French fries and crisps. The Ethiopian varieties have a low content of dry matter and therefore the products have a low quality. Also with processed products it is possible to generate more added value in the production chain. This should result in a better income for the farmer as a potato grower.

6. Reflection on the internship

What I learned the most from this internship is to adjust to a completely new environment. In The Netherlands I am used to live close to my family and friends. In Africa on the other hand, I was all by myself. I had to adapt a lot to my new housing, new workplace and the crowded city. In the beginning it was pretty hard. I invested a lot though in making contact and getting to understand the cultural behavior of the Ethiopian people. I did this by trying to learn some words of the national language which is Amharic. Moreover, I tried the national food and I travelled by local minibuses. In the end I felt that I was part of the city Addis Ababa and its people.
This was more successful than I could have imaged. When my father and girlfriend visited me, they told me they were very surprised that I could speak Amharic and I have been making Ethiopian friends. I liked it to show them around and introduce them to those friends. Besides, I explained them what I have been learning about the Ethiopian culture.

Another learning outcome of this internship was how to lay out a field experiment and doing the measurements in a correct way. The data would be used for several scientific purposes. Not only for the PhD research of Biructawit, but also for research with regards to GxE and QTLxE analyses. From the start of the experiment it was clear that Biructawit and I had to agree on how we did the measurements, that met the criteria as much as possible. This agreement was needed because sometimes I had to work alone in the field or coordinate the work done by the research center's technicians, whilst Biructawit was not present. As a result of the agreement made before it was easy to update each other. Before leaving Ethiopia, Biructawit and myself evaluated the work I have done. Biructawit especially appreciated the practical knowledge and assistance concerning the fieldwork. I felt very satisfied that I could apply the theory I learned the years before.

Strengths in this working environment which I experienced are dedication, perseverance and my skills in potato cultivation. During the project I showed dedication and perseverance for example when the potatoes did not arrive on time. Instead I started to read, prepare labels and discuss the possibilities of the experiment. Moreover, during weekends and holidays I continued working on the project. Furthermore, Biructawit and myself complemented each other. My skills in potato cultivation were useful, compared to Biructawit who had more research skills.
During the internship I experienced also a couple of weak points, which I have to consider in my future career. Because I am so dedicated to the field work, I have problems with making a good planning which includes sufficient time for writing the report. As a result, less attention was paid to the development of the scientific writing skills. Now I am aware of this, I have to give more priority to this part of the work. I think I can achieve this by means of a clear definition of the time I can spend in the field.

In relation to my professional development, this internship contributed to an insight in the Ethiopian potato cultivation. For a breeder, a profession I aim for, it is useful to know how potatoes are grown and used in different environments. Where growers and consumers all have different demands concerning the potato crop. This insight helps me to set breeding goals and design breeding programmes in the future.

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Appendices

Appendix A Multiple comparison date of emergence
Appendix B Multiple comparison of main stem number
Appendix C Flowering in the CxE population and the tetraploid cultivars.

Appendix A Multiple comparison date of emergence

Result of the Fisher's unprotected least significant difference test. The letters indicate the significant differences between the CxE genotypes based on the LSD-value of 2.4104. For example ‘a’ means that genotypes CE-617 till CE-670 belong to the same group and ‘b’ means that genotypes CE-618 till CE-671 belong to another group than ‘a’ etc. The genotypes are sorted ascending, so the genotypes that emerged the first are on top.

Genotype	Mean
CE-617	11.67 a
CE-618	11.75 ab
CE-292	12.08 abc
CE-663	12.33 abcd
CE-613	12.50 abcde
CE-155	12.72 abcdef
CE-350	12.75 abcdef
CE-612	12.83 abcdefg
CE-619	12.83 abcdefg
CE-698	13.00 abcdefgh
CE-722	13.00 abcdefgh
CE-665	13.17 abcdefghi
CE-744	13.17 abcdefghi
CE-616	13.25 abcdefghij
CE-737	13.33 abcdefghijk
CE-222	13.42 abcdefghijkl
CE-632	13.42 abcdefghijkl
CE-642	13.42 abcdefghijkl
CE-694	13.42 abcdefghijkl
CE-277	13.50 abcdefghijklm
CE-624	13.75 abcdefghijklmn
CE-651	13.75 abcdefghijklmn
CE-602	13.83 abcdefghijklmno
CE-681	13.83 abcdefghijklmno
CE-666	13.92 abcdefghijklmnop
CE-200	13.97 abcdefghijklmnopq
CE-670	14.06 abcdefghijklmnopqr
CE-47	14.08 bcdefghijklmnopqr
CE-625	14.08 bcdefghijklmnopqr
CE-639	14.08 bcdefghijklmnopqr
CE-654	14.08 bcdefghijklmnopqr
CE-671	14.08 bcdefghijklmnopqr
CE-605	14.17 cdefghijklmnopqrs
CE-724	14.17 cdefghijklmnopqrs
CE-667	14.25 cdefghijklmnopqrst
CE-777	14.25 cdefghijklmnopqrst
CE-650	14.33 cdefghijklmnopqrstu
CE-675	14.33 cdefghijklmnopqrstu
CE-739	14.33 cdefghijklmnopqrstu
CE-615	14.42 cdefghijklmnopqrstuv
CE-633	14.42 cdefghijklmnopqrstuv
CE-734	14.42 cdefghijklmnopqrstuv
CE-778	14.42 cdefghijklmnopqrstuv
CE-661	14.50 defghijklmnopqrstuvw
CE-691	14.50 defghijklmnopqrstuvw

CE-697	14.50	defghijklmnopqrstuvw
CE-699	14.58	defghijklmnopqrstuvwx
CE-711	14.63	defghijklmnopqrstuvwxy
CE-627	14.67	defghijklmnopqrstuvwxy
CE-630	14.67	defghijklmnopqrstuvwxy
CE-638	14.67	defghijklmnopqrstuvwxy
CE-673	14.67	defghijklmnopqrstuvwxy
CE-676	14.67	defghijklmnopqrstuvwxy
CE-729	14.67	defghijklmnopqrstuvwxy
CE-748	14.67	defghijklmnopqrstuvwxy
CE-755	14.67	defghijklmnopqrstuvwxy
CE-760	14.67	defghijklmnopqrstuvwxy
CE-678	14.72	defghijklmnopqrstuvwxy
CE-628	14.75	efghijklmnopqrstuvwxy
CE-713	14.75	efghijklmnopqrstuvwxy
CE-078	14.83	efghijklmnopqrstuvwxyz
CE-210	14.83	efghijklmnopqrstuvwxyz
CE-601	14.83	efghijklmnopqrstuvwxyz
CE-683	14.83	efghijklmnopqrstuvwxyz
CE-732	14.83	efghijklmnopqrstuvwxyz
CE-688	14.89	efghijklmnopqrstuvwxyzA
CE-723	14.89	efghijklmnopqrstuvwxyzA
CE-447	14.92	fghijklmnopqrstuvwxyzA
CE-604	14.92	fghijklmnopqrstuvwxyzA
CE-611	14.92	fghijklmnopqrstuvwxyzA
CE-664	14.92	fghijklmnopqrstuvwxyzA
CE-719	14.92	fghijklmnopqrstuvwxyzA
CE-766	14.92	fghijklmnopqrstuvwxyzA
CE-686	15.00	fghijklmnopqrstuvwxyzAB
CE-669	15.06	fghijklmnopqrstuvwxyzABC
CE-159	15.08	fghijklmnopqrstuvwxyzABC
CE-171	15.08	fghijklmnopqrstuvwxyzABC
CE-701	15.08	fghijklmnopqrstuvwxyzABC
CE-759	15.08	fghijklmnopqrstuvwxyzABC
CE-788	15.08	fghijklmnopqrstuvwxyzABC
CE-695	15.17	ghijklmnopqrstuvwxyzABCD
CE-765	15.17	ghijklmnopqrstuvwxyzABCD
CE-100	15.25	hijklmnopqrstuvwxyzABCDE
CE-607	15.25	hijklmnopqrstuvwxyzABCDE
CE-658	15.25	hijklmnopqrstuvwxyzABCDE
CE-672	15.25	hijklmnopqrstuvwxyzABCDE
CE-32	15.33	hijklmnopqrstuvwxyzABCDEF
CE-687	15.33	hijklmnopqrstuvwxyzABCDEF
CE-17	15.42	ijklmnopqrstuvwxyzABCDEF
CE-603	15.42	ijklmnopqrstuvwxyzABCDEF
CE-69	15.42	ijklmnopqrstuvwxyzABCDEF
CE-609	15.47	ijklmnopqrstuvwxyzABCDEF
CE-677	15.50	ijklmnopqrstuvwxyzABCDEF
CE-707	15.50	ijklmnopqrstuvwxyzABCDEF
CE-660	15.58	jklmnopqrstuvwxyzABCDEFG
CE-738	15.58	jklmnopqrstuvwxyzABCDEFG
CE-207	15.67	klmnopqrstuvwxyzABCDEFG
CE-692	15.67	klmnopqrstuvwxyzABCDEFG
CE-202	15.75	lmnopqrstuvwxyzABCDEFGH
CE-637	15.75	lmnopqrstuvwxyzABCDEFGH
CE-668	15.75	lmnopqrstuvwxyzABCDEFGH

CE-756	15.75	lmnopqrstuvwxyzABCDEFGH
CE-614	15.83	mnopqrstuvwxyzABCDEFGHI
C-parent	15.92	nopqrstuvwxyzABCDEFGHI
CE-233	16.08	nopqrstuvwxyzABCDEFGHIJ
CE-740	16.08	nopqrstuvwxyzABCDEFGHIJ
CE-657	16.17	opqrstuvwxyzABCDEFGHIJK
CE-716	16.17	opqrstuvwxyzABCDEFGHIJK
CE-706	16.25	pqrstuvwxyzABCDEFGHIJKL
CE-626	16.33	qrstuvwxyzABCDEFGHIJKL
CE-631	16.33	qrstuvwxyzABCDEFGHIJKL
CE-640	16.33	qrstuvwxyzABCDEFGHIJKL
CE-276	16.42	rstuvwxyzABCDEFGHIJKLM
CE-710	16.42	rstuvwxyzABCDEFGHIJKLM
CE-646	16.50	stuvwxyzABCDEFGHIJKLM
CE-690	16.50	stuvwxyzABCDEFGHIJKLM
CE-72	16.50	stuvwxyzABCDEFGHIJKLM
CE-721	16.50	stuvwxyzABCDEFGHIJKLM
CE-750	16.50	stuvwxyzABCDEFGHIJKLM
CE-717	16.58	tuvwxyzABCDEFGHIJKLMN
CE-746	16.58	tuvwxyzABCDEFGHIJKLMN
CE-127	16.64	tuvwxyzABCDEFGHIJKLMN
CE-102	16.67	uvwxyzABCDEFGHIJKLMN
CE-252	16.67	uvwxyzABCDEFGHIJKLMN
CE-689	16.67	uvwxyzABCDEFGHIJKLMN
CE-647	16.75	vwxyzABCDEFGHIJKLMN
CE-648	16.75	vwxyzABCDEFGHIJKLMN
CE-693	16.75	vwxyzABCDEFGHIJKLMN
CE-696	16.75	vwxyzABCDEFGHIJKLMN
CE-720	16.75	vwxyzABCDEFGHIJKLMN
CE-754	16.75	vwxyzABCDEFGHIJKLMN
CE-635	16.83	wxyzABCDEFGHIJKLMNO
CE-67	16.92	xyzABCDEFGHIJKLMNOP
CE-700	16.92	xyzABCDEFGHIJKLMNOP
E-parent	16.92	xyzABCDEFGHIJKLMNOP
CE-27	17.00	yzABCDEFGHIJKLMNOP
CE-655	17.17	zABCDEFGHIJKLMNOP
CE-753	17.17	zABCDEFGHIJKLMNOP
CE-684	17.25	ABCDEFGHIJKLMNOPQ
CE-622	17.33	BCDEFGHIJKLMNOPQR
CE-659	17.33	BCDEFGHIJKLMNOPQR
CE-195	17.42	CDEFGHIJKLMNOPQR
CE-70	17.42	CDEFGHIJKLMNOPQR
CE-703	17.42	CDEFGHIJKLMNOPQR
CE-762	17.42	CDEFGHIJKLMNOPQR
CE-731	17.50	DEFGHIJKLMNOPQR
CE-110	17.58	EFGHIJKLMNOPQRS
CE-141	17.58	EFGHIJKLMNOPQRS
CE-682	17.58	EFGHIJKLMNOPQRS
CE-761	17.58	EFGHIJKLMNOPQRS
CE-653	17.67	FGHIJKLMNOPQRST
CE-776	17.72	FGHIJKLMNOPQRST
CE-680	17.92	GHIJKLMNOPQRSTU
CE-82	18.08	HIJKLMNOPQRSTU
CE-656	18.22	IJKLMNOPQRSTU
CE-705	18.33	JKLMNOPQRSTU
CE-250	18.36	JKLMNOPQRSTU

CE-764	18.53	KLMNOPQRSTU
CE-742	18.58	LMNOPQRSTU
CE-298	18.61	LMNOPQRSTU
CE-636	18.64	LMNOPQRSTU
CE-679	18.75	MNOPQRSTU
CE-704	18.92	NOPQRSTU
CE-715	19.17	OPQRSTUV
CE-712	19.25	PQRSTUV
CE-11	19.58	QRSTUV
CE-165	19.72	RSTUV
CE-763	19.92	STUV
CE-620	20.01	TUV
CE-115	20.28	UV
CE-758	21.47	V

Appendix B Multiple comparison of main stem number

Result of the Fisher's unprotected least significant difference test. For this comparison the natural log data are used. The letters indicate the significant differences between the CxE genotypes based on the LSD-value of 0.362. For example 'a' means that genotypes CE-617 till CE-670 belong to the same group and 'b' means that genotypes CE-618 till CE-671 belong to another group than 'a' etc. The genotypes are sorted ascending, so the genotypes with the least stems are on top.

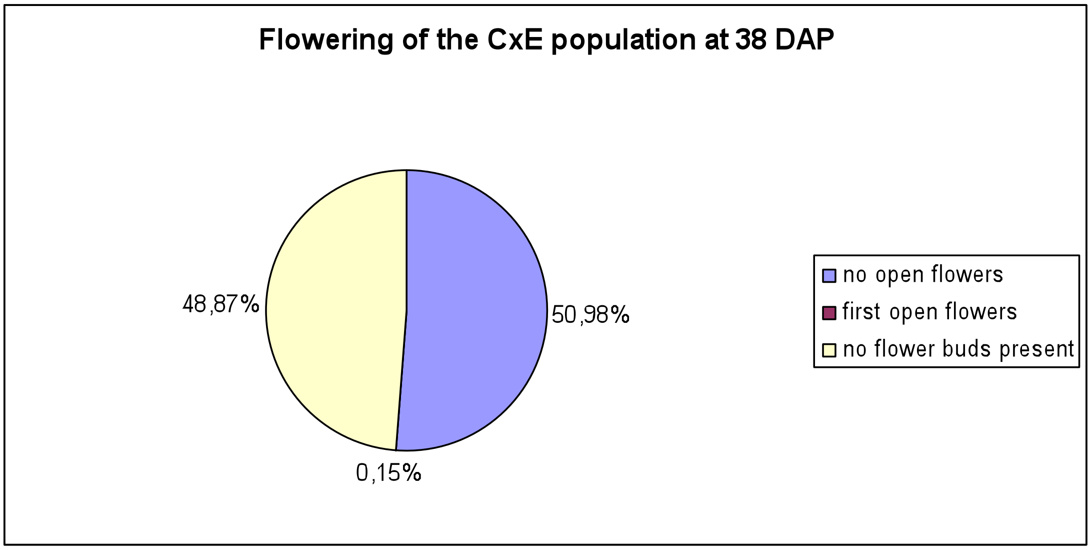
genotype	Mean (ln)	mean	
CE-72	0,842	2,321	a
CE-646	0,942	2,565	ab
CE-756	0,963	2,620	abc
CE-788	1,009	2,743	abcd
CE-620	1,036	2,818	abcde
CE-704	1,042	2,835	abcde
CE-738	1,077	2,936	abcdef
CE-622	1,081	2,948	abcdef
CE-762	1,119	3,062	abcdefg
CE-625	1,121	3,068	abcdefgh
CE-716	1,121	3,068	abcdefgh
CE-636	1,121	3,068	abcdefgh
CE-70	1,139	3,124	abcdefghi
CE-611	1,141	3,130	abcdefghij
CE-110	1,144	3,139	abcdefghijk
CE-758	1,150	3,158	abcdefghijkl
CE-684	1,152	3,165	abcdefghijklm
CE-115	1,154	3,171	abcdefghijklm
CE-276	1,154	3,171	abcdefghijklm
CE-155	1,156	3,177	abcdefghijklmn
CE-681	1,160	3,190	abcdefghijklmno
CE-27	1,173	3,232	abcdefghijklmno
CE-742	1,192	3,294	abcdefghijklmnop
CE-731	1,201	3,323	abcdefghijklmnopq
CE-703	1,205	3,337	bcdefghijklmnopqr
CE-688	1,212	3,360	bcdefghijklmnopqr
CE-682	1,215	3,370	bcdefghijklmnopqrs
CE-633	1,218	3,380	bcdefghijklmnopqrs
CE-127	1,230	3,421	bcdefghijklmnopqrst
CE-637	1,240	3,456	bcdefghijklmnopqrstu
CE-753	1,240	3,456	bcdefghijklmnopqrstu
CE-687	1,273	3,572	bcdefghijklmnopqrstuv
CE-635	1,274	3,575	bcdefghijklmnopqrstuv
CE-705	1,276	3,582	bcdefghijklmnopqrstuv
CE-765	1,287	3,622	bcdefghijklmnopqrstuvw
CE-200	1,289	3,629	bcdefghijklmnopqrstuvw
CE-651	1,289	3,629	bcdefghijklmnopqrstuvw
CE-82	1,290	3,633	bcdefghijklmnopqrstuvw
CE-740	1,293	3,644	bcdefghijklmnopqrstuvw
CE-078	1,296	3,655	bcdefghijklmnopqrstuvwx
CE-250	1,297	3,658	bcdefghijklmnopqrstuvwxy
CE-712	1,301	3,673	bcdefghijklmnopqrstuvwxyz
CE-711	1,317	3,732	cdefghijklmnopqrstuvwxyzA

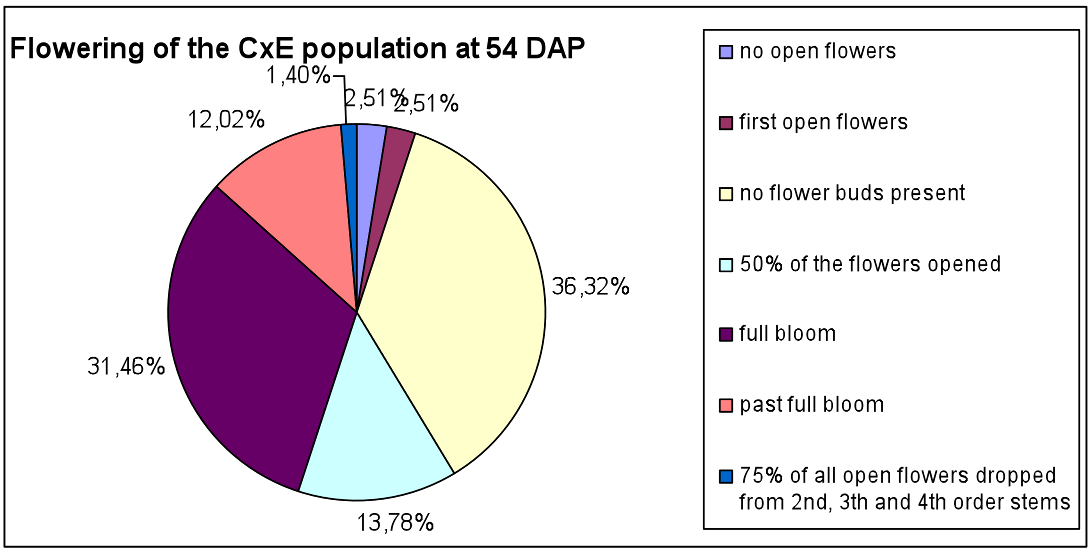
CE-677	1,317	3,732	cdefghijklmnopqrstuvwxyzA
CE-607	1,326	3,766	defghijklmnopqrstuvwxyzAB
CE-614	1,330	3,781	defghijklmnopqrstuvwxyzABC
CE-720	1,330	3,781	defghijklmnopqrstuvwxyzABC
CE-680	1,336	3,804	defghijklmnopqrstuvwxyzABC
CE-631	1,336	3,804	defghijklmnopqrstuvwxyzABC
CE-233	1,337	3,808	defghijklmnopqrstuvwxyzABC
CE-32	1,339	3,815	defghijklmnopqrstuvwxyzABC
CE-729	1,350	3,857	defghijklmnopqrstuvwxyzABCD
CE-666	1,356	3,881	defghijklmnopqrstuvwxyzABCDE
CE-659	1,360	3,896	defghijklmnopqrstuvwxyzABCDE
CE-627	1,363	3,908	defghijklmnopqrstuvwxyzABCDE
CE-734	1,369	3,931	defghijklmnopqrstuvwxyzABCDEF
CE-675	1,370	3,935	defghijklmnopqrstuvwxyzABCDEF
CE-777	1,370	3,935	defghijklmnopqrstuvwxyzABCDEF
CE-696	1,377	3,963	efghijklmnopqrstuvwxyzABCDEFG
CE-630	1,385	3,995	efghijklmnopqrstuvwxyzABCDEFG
CE-737	1,387	4,003	efghijklmnopqrstuvwxyzABCDEFGH
CE-692	1,396	4,039	efghijklmnopqrstuvwxyzABCDEFGHI
CE-601	1,404	4,071	fghijklmnopqrstuvwxyzABCDEFGHI
CE-639	1,404	4,071	fghijklmnopqrstuvwxyzABCDEFGHI
CE-672	1,404	4,071	fghijklmnopqrstuvwxyzABCDEFGHI
CE-632	1,412	4,104	fghijklmnopqrstuvwxyzABCDEFGHI
CE-669	1,416	4,121	fghijklmnopqrstuvwxyzABCDEFGHIJ
CE-207	1,417	4,125	fghijklmnopqrstuvwxyzABCDEFGHIJ
CE-759	1,419	4,133	fghijklmnopqrstuvwxyzABCDEFGHIJK
CE-750	1,420	4,137	fghijklmnopqrstuvwxyzABCDEFGHIJK
CE-776	1,430	4,179	fghijklmnopqrstuvwxyzABCDEFGHIJK
CE-679	1,432	4,187	fghijklmnopqrstuvwxyzABCDEFGHIJK
CE-713	1,444	4,238	ghijklmnopqrstuvwxyzABCDEFGHIJKL
CE-693	1,451	4,267	ghijklmnopqrstuvwxyzABCDEFGHIJKLM
CE-683	1,455	4,284	ghijklmnopqrstuvwxyzABCDEFGHIJKLMN
CE-102	1,459	4,302	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNO
CE-653	1,462	4,315	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNO
CE-638	1,464	4,323	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNO
CE-648	1,468	4,341	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNOP
CE-755	1,468	4,341	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNOP
CE-671	1,470	4,349	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQ
CE-707	1,473	4,362	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQ
CE-761	1,473	4,362	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQ
CE-647	1,477	4,380	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQ
CE-655	1,477	4,380	ghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQ
CE-656	1,481	4,397	hijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQ
CE-11	1,482	4,402	hijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQ
CE-277	1,483	4,406	ijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQ
CE-141	1,497	4,468	ijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQR
CE-67	1,497	4,468	ijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQR
CE-604	1,501	4,486	jklmnopqrstuvwxyzABCDEFGHIJKLMNOPQR
CE-690	1,503	4,495	klmnopqrstuvwxyzABCDEFGHIJKLMNOPQR
CE-654	1,505	4,504	klmnopqrstuvwxyzABCDEFGHIJKLMNOPQR
CE-159	1,510	4,527	lmnopqrstuvwxyzABCDEFGHIJKLMNOPQR
CE-686	1,513	4,540	mnopqrstuvwxyzABCDEFGHIJKLMNOPQR
CE-298	1,516	4,554	nopqrstuvwxyzABCDEFGHIJKLMNOPQR
E-parent	1,521	4,577	opqrstuvwxyzABCDEFGHIJKLMNOPQR

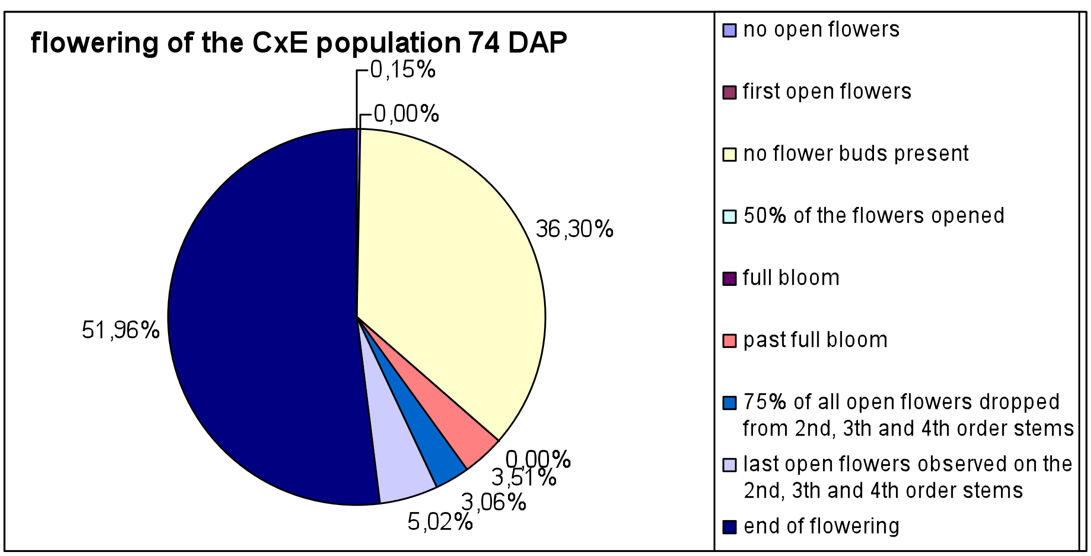
CE-668	1,536	4,646	pqrstuvwxyzABCDEFGHIJKLMNOPQRS
CE-678	1,540	4,665	pqrstuvwxyzABCDEFGHIJKLMNOPQRS
CE-100	1,551	4,716	pqrstuvwxyzABCDEFGHIJKLMNOPQRS
CE-723	1,551	4,716	pqrstuvwxyzABCDEFGHIJKLMNOPQRS
CE-350	1,555	4,735	qrstuvwxyzABCDEFGHIJKLMNOPQRS
CE-673	1,557	4,745	qrstuvwxyzABCDEFGHIJKLMNOPQRS
CE-603	1,561	4,764	qrstuvwxyzABCDEFGHIJKLMNOPQRS
CE-165	1,562	4,768	qrstuvwxyzABCDEFGHIJKLMNOPQRS
CE-691	1,567	4,792	rstuvwxyzABCDEFGHIJKLMNOPQRST
CE-663	1,567	4,792	rstuvwxyzABCDEFGHIJKLMNOPQRST
CE-640	1,573	4,821	stuvwxyzABCDEFGHIJKLMNOPQRST
CE-715	1,575	4,831	stuvwxyzABCDEFGHIJKLMNOPQRST
CE-617	1,582	4,865	tuvwxyzABCDEFGHIJKLMNOPQRST
CE-615	1,592	4,914	uvwxyzABCDEFGHIJKLMNOPQRST
CE-764	1,592	4,914	uvwxyzABCDEFGHIJKLMNOPQRST
CE-195	1,594	4,923	uvwxyzABCDEFGHIJKLMNOPQRST
CE-721	1,599	4,948	uvwxyzABCDEFGHIJKLMNOPQRSTU
CE-69	1,612	5,013	vwxyzABCDEFGHIJKLMNOPQRSTU
CE-667	1,621	5,058	vwxyzABCDEFGHIJKLMNOPQRSTUV
CE-171	1,622	5,063	vwxyzABCDEFGHIJKLMNOPQRSTUV
CE-746	1,625	5,078	vwxyzABCDEFGHIJKLMNOPQRSTUV
CE-724	1,630	5,104	vwxyzABCDEFGHIJKLMNOPQRSTUVW
CE-676	1,632	5,114	vwxyzABCDEFGHIJKLMNOPQRSTUVW
CE-642	1,645	5,181	wxyzABCDEFGHIJKLMNOPQRSTUVWX
CE-722	1,648	5,197	wxyzABCDEFGHIJKLMNOPQRSTUVWX
CE-605	1,649	5,202	wxyzABCDEFGHIJKLMNOPQRSTUVWX
CE-619	1,656	5,238	xyzABCDEFGHIJKLMNOPQRSTUVWX
CE-292	1,657	5,244	yzABCDEFGHIJKLMNOPQRSTUVWX
CE-697	1,661	5,265	zABCDEFGHIJKLMNOPQRSTUVWX
CE-732	1,671	5,317	ABCDEFGHIJKLMNOPQRSTUVWXY
CE-660	1,681	5,371	BCDEFGHIJKLMNOPQRSTUVWXY
CE-17	1,682	5,376	BCDEFGHIJKLMNOPQRSTUVWXY
CE-658	1,683	5,382	BCDEFGHIJKLMNOPQRSTUVWXY
CE-699	1,690	5,419	CDEFGHIJKLMNOPQRSTUVWXY
CE-710	1,706	5,507	DEFGHIJKLMNOPQRSTUVWXY
CE-695	1,709	5,523	DEFGHIJKLMNOPQRSTUVWXY
CE-609	1,712	5,540	EFGHIJKLMNOPQRSTUVWXY
CE-252	1,713	5,546	EFGHIJKLMNOPQRSTUVWXY
CE-760	1,713	5,546	EFGHIJKLMNOPQRSTUVWXY
CE-657	1,714	5,551	EFGHIJKLMNOPQRSTUVWXY
CE-689	1,729	5,635	FGHIJKLMNOPQRSTUVWXY
CE-700	1,732	5,652	GHIJKLMNOPQRSTUVWXYZ
CE-748	1,733	5,658	GHIJKLMNOPQRSTUVWXYZ
CE-766	1,747	5,737	HIJKLMNOPQRSTUVWXYZ
CE-222	1,749	5,749	IJKLMNOPQRSTUVWXYZ
CE-670	1,775	5,900	JKLMNOPQRSTUVWXYZ
CE-744	1,780	5,930	KLMNOPQRSTUVWXYZ
CE-447	1,780	5,930	KLMNOPQRSTUVWXYZ
CE-602	1,796	6,025	LMNOPQRSTUVWXYZ1
CE-701	1,804	6,074	LMNOPQRSTUVWXYZ1
CE-717	1,808	6,098	MNOPQRSTUVWXYZ1
CE-210	1,814	6,135	NOPQRSTUVWXYZ1
CE-694	1,817	6,153	NOPQRSTUVWXYZ1
CE-618	1,820	6,172	OPQRSTUVWXYZ1
CE-778	1,828	6,221	PQRSTUVWXYZ1
CE-763	1,830	6,234	QRSTUVWXYZ1

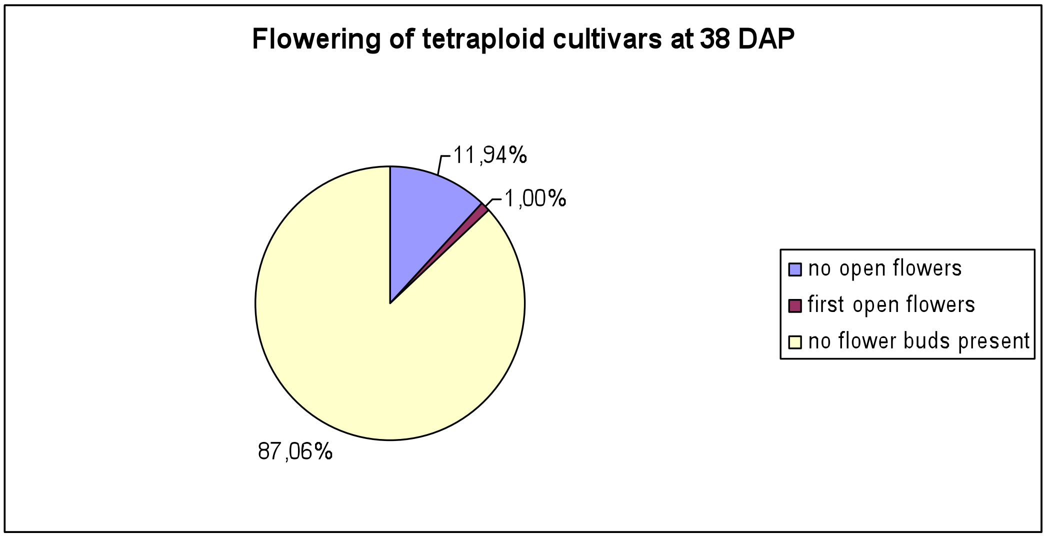
CE-739	1,845	6,328	RSTUVWXYZ1
CE-613	1,851	6,366	RSTUVWXYZ1
CE-665	1,854	6,385	RSTUVWXYZ1
C-parent	1,858	6,411	RSTUVWXYZ1
CE-202	1,896	6,659	STUVWXYZ1
CE-626	1,896	6,659	STUVWXYZ1
CE-628	1,928	6,876	TUVWXYZ12
CE-624	1,956	7,071	UVWXYZ12
CE-612	1,974	7,199	VWXYZ12
CE-706	1,975	7,207	VWXYZ12
CE-698	1,980	7,243	VWXYZ12
CE-719	1,991	7,323	WXYZ12
CE-754	2,004	7,419	XYZ12
CE-664	2,024	7,569	YZ12
CE-650	2,093	8,109	Z12
CE-616	2,147	8,559	12
CE-47	2,147	8,559	12
CE-661	2,262	9,602	2

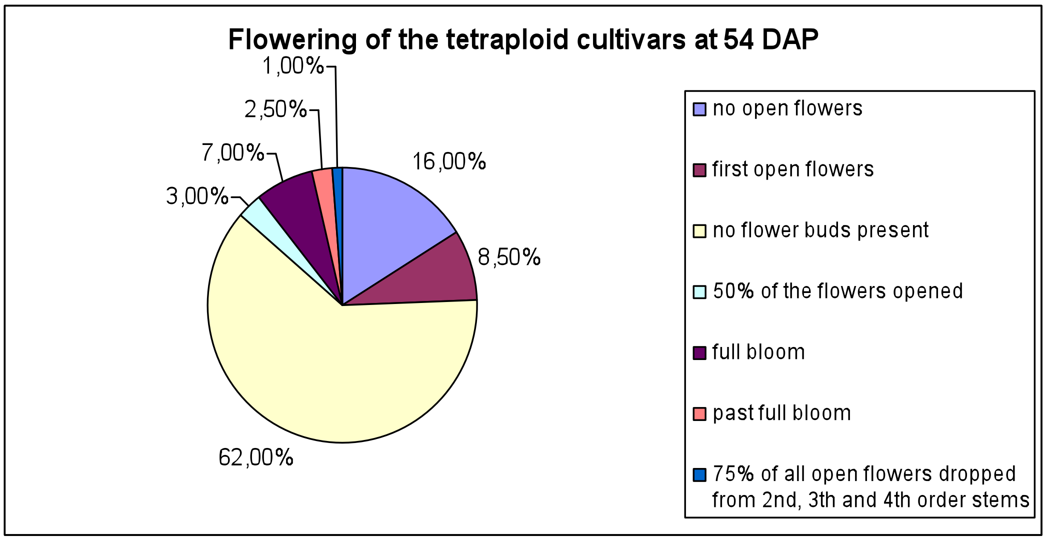
Appendix C Flowering in the the CxE population and the tetraploid cultivars

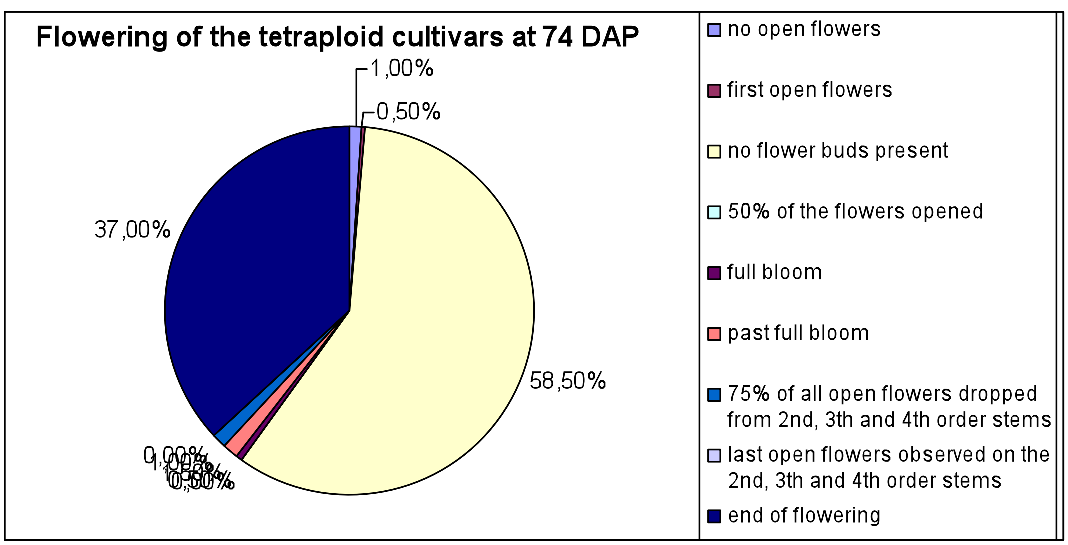







Flowering of tetraploid cultivars at 38 DAP
11,94%
1,00%
87,06%
no open flowers
first open flowers
no flower buds present


Flowering of the tetraploid cultivars at 54 DAP
1,00%
2,50%
7,00%
3,00%
16,00%
8,50%
62,00%
no open flowers
first open flowers
no flower buds present
50% of the flowers opened
full bloom
past full bloom
75% of all open flowers dropped from 2nd, 3th and 4th order stems


Flowering of the tetraploid cultivars at 74 DAP
1,00%
0,50%
37,00%
58,50%
no open flowers
first open flowers
no flower buds present
50% of the flowers opened
full bloom
past full bloom
75% of all open flowers dropped from 2nd, 3th and 4th order stems
last open flowers observed on the 2nd, 3th and 4th order stems
end of flowering