Bachelor Assignment

Development of the Crossing Designer

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Preface

This document is the Bachelor Assignment of Iris van den Nieuwenhuizen. It is the final assignment for the Bachelor Industrial Design at the University of Twente. For the Bachelor Assignment there has been done an internship at Agri Information Partners (AIP) in Wageningen. AIP is a company that makes software for plant breeding companies. The Internship contained a specific assignment for AIP where is worked on for 3 months.

Besides my study Industrial Design, I also start studying Plant Breeding. Therefore doing my Bachelor Assignment at AIP gave me the opportunity to combine both fields of interests. During the Bachelor Assignment I had the opportunity to talk with different breeders and visit multiple breeding companies. The breeders and the companies were highly involved, during the development of the crossing designer. I really enjoyed translating the breeder's needs into a software product. During my Bachelor Assignment, AIP involved me closely to the company, I really felt part of it.

I want to thank Berno van der Geest, my supervisor at AIP, for giving me the internship and all his support during my time at AIP. He helped me with making appointments with breeders and joined me on several visits, but also gave me the trust to do it alone. He was very enthusiastic about my ideas and way of working which was sometimes different from the way AIP was used to.
I want to thank the breeders E. Spaans, J. Bucher, H. Sasbrink, R. Steentjes, B. van Haperen, M. de Hertogh, A. van Doesum, S. Allefs, and M. Vossen for providing me information and thinking with me about the development of the crossing designer. They gave me a lot of information on how they use software within their job, but they also showed me what their job exactly is.

Enjoy reading!

Index

Introduction

AIP is a company that makes software to support breeding activities. It is a small company, that develops their own breeding software and software specific made for breeding companies. E-Brida is one of AIP's software application and it supports breeding administration in generative as well as in vegetative plant breeding[1]. Breeders use E-Brida as a support software in the whole process of plant breeding[2].

Plant breeding is the creation of plants (offspring) with improved traits. Favourable traits for the new variety are selected from existing varieties of plants, which have one or more of those favourable traits. The goal of breeding is to get the genetic material of these favourable traits into the genome of a new variety. The new variety is seen as a super plant, thus only the genetic material of favourable traits should be in the genome of the new variety. In order to accomplish this plants with different favourable traits are combined by crossing, backcrossing or genetic modification[3].
After combining the plants, the offspring is received. The next step of the breeding process is the selection of plants from the offspring. Plants are selected on whether certain traits are present or not. To get the genetic material of a certain trait into the genome of the offspring it is important that the parental plants have the genetic material to be able to give it to their offspring. To create a new variety it takes multiple generations of plants, and within each generation selection takes place to find/create the new variety with the ideal combinations of genetic material. Selection is an important step within the breeding process because it influences the success of the new variety and the time to create the new variety[4].

Currently in E-Brida crosses are made starting with selecting the parental plants. The breeder has to select the parental plants and cross them with each other. This is the first moment within the breeding processes that E-Brida supports. Therefore breeders don't think they have enough support from E-Brida because they already want support in earlier stages of the breeding process. Breeders would like to have help with finding and combining plant material, to get the most promising combinations.
The improvement on this part of E-Brida has created a new project at AIP, the design of a crossing-designer. This means that AIP want to add (or take apart the current support to make crosses and improvements from E-Brida) a separate function, which supports breeders in the creation of crosses. The function will support the start of the breeding process and therefore the start of using E-Brida[5].

1. *Vegetative plant breeding*: breeding of asexual reproducing plants.
   Generative plant breeding: breeding of sexual reproducing plants.
2. Website: Agri Information Partners, 2014
3. *Crossing:* reproduction of 2 varieties of plants with favourable traits.
   Backcrossing: reproduction a plant variety with a wild relative plant with 1 favourable trait.
   Genetic modification: DNA implementation of a variety into another variety.
4. Breedwise, 2004
5. Agri Information Partners, 2013

AIP already has an idea of what the function of the crossing designer has to do and which results it should give, but not how the crossing designer should work to give these results. They want to adapt the crossing designer to the consumer's needs, to make sure that the users will use it. Therefore they want to know how they can support breeders in the current process of making crosses. This information is needed to create a crossing designer which is useful for breeders by supporting the making of crosses. The information will be used for thinking of possibilities of how the crossing designer should work and look like. These ideas will be placed in a morphological scheme, and from the morphological scheme three concepts will be generated. For all three concepts a prototype will be made, which will be tested by the users. The results will give a final advice to AIP how the crossing designer should work to support breeders during the process of making crosses[1].

1. Appendix I, Assignment

Background Information

Plant breeding is the creation of plants with improved traits, focussing on the creation of new varieties. Results of a variety and improvement are determined by the phenotype, which is the sum of influence of the genotype and the environment. Phenotype can be defined as a form taken by a character. Genotypes can be defined as the allelic (genetic) combinations underlying phenotypes[1]. The improvement of varieties is focused on 6 goals; yield, quality, harvest security, harvest time, breeding costs and new features[2].

1. Griffiths, 2012
2. Breedwise, 2004

Reproduction of Plants

Plants can have vegetative and generative reproduction. Vegetative reproduction of plants doesn't have fertilization and new plants are grown from parts of the parental plant. The main characteristic is that the genotype of the new grown plant is identical to the plant of which a part is taken from. Generative reproduction does have fertilization and there are seeds produced. Within generative reproduction self-pollinating and cross-pollinating plants are distinguished. With self-pollination the plant fertilizes itself. The genetic result of self-pollinating plants is that in the end (after generations of self-pollination) they tend to become homozygote *(figure 1)*. This is based on the rules of Mendel about inheritance. With cross-pollination the genes of different plants are making new combinations. In the group of plants that can cross, different genotypes are represented. Therefore the different genotypes come back in the generations of plants and therefore the group cross-pollinated plants don't become uniform[3].

AA x AA	Aa x Aa	aa x aa
↓	↓	↓
AA	¼ AA + ½ Aa + ¼ aa	aa

gure 1. Genotype spreading of the ffspring of self pollinating plants.

3. Breedwise, 2004

Breeding of Vegetative Reproduction Plants

The vegetative offspring of a plant is a clone, and has an identical genotype as the parental plant. Although the genotype is identical the plants mostly have a heterozygote genotype. To develop clone varieties two favourable parental clone varieties are combined with each other[4]. Within the F1[5] there is already a lot of segregation, the plants with the favourable traits are selected. In the beginning selection is broad and mostly about qualitative traits. From selected favourable plants, lines are produced by vegetative reproduction. Selection will take place what will result in less clones, but more plants of a clone[6].

4. Appendix II, figure 1
5. *F1*: is the first generation (offspring) of crossing the parental plants
6. Breedwise, 2004

Breeding of Generative Reproduction Plants

As described before generative reproducing plants can be divided in self-pollinating plants and cross-pollinating plants. They need to be treated separately from each other for breeding programs. With self-pollination, homozygote plants will give homozygote progeny and heterozygote plants will give half heterozygote progeny and half homozygote progeny[7]. With each generation, the group heterozygote will be halved. The progeny of self-pollinating plants is called a line, after generation the line will become

7. Appendix II, figure 2

mainly homozygote. Self-pollinating varieties first have to be crossed with another plant, which has the favourable trait to be introduced. As self-pollinating plants are mostly homozygote, the F1 generation will become all heterozygote. The F1 generations can start with self-pollination and from the F2 generation selection can take place. The best lines of plant will be chosen each generation and used further in the breeding process. During the generations more and more plants will become homozygote.

With cross-pollination the genes of different plants are combined and therefore homozygote and heterozygotes are represented in the group of plants[1]. Mother plants which are fertilized with pollen of different 'father' plants, result in a progeny that have all the same mother and have a different father. The progeny is described as a half-sib family. If two plants are crossed with each other, the progeny has the same father and mother. The progeny is described as a full-sib family (population). When plants are combined, the progeny in the F1 will be all different from each other and selection of the plant can already take place. The best plants are chosen and these half-sib families will be kept separate from each other. In each generation the best plants of the best families will be selected to achieve the breeding goal[2].

1. Appendix II, figure 3

2. Breedwise, 2004

Hybrid Varieties

Heterosis is the improved quality of the offspring, because of combining two non-relatives plant with each other. The combination of relative plants can give less good quality because of inbreeding. Heterosis is when two inbreed lines are crossed and the progeny has better quality then the parental plants. The progeny are called hybrids and are considered to be heterozygote, because the parental plants are mostly homozygote. To create hybrid varieties there should be enough plant material with different backgrounds. From this material inbreed lines or homozygote lines need to be created. Then crosses can be made and selection on the best hybrids can take place. Hybrid lines are for seed companies very profitable, because farmers can't use the progeny of the hybrids (because they are heterozygote, crossing them will give progeny with segregation) and therefore have to buy each time new seeds[3].

3. Breedwise, 2004

Analysis

During the analysis there will be looked for more information which is relevant to create a successful crossing designer. The crossing designer is still an undefined idea. During the analysis information will be collected to find out how this idea could become a successful product for AIP. AIP already has decided that there is enough knowledge within the company to create a product as the crossing designer and therefore during the analysis there will be looked for information about how the crossing designer should work and should look like.
In this chapter the analysis are described, which will result in requirements and specifications for the design of the crossing designer. There will be taken a look on the function of the crossing designer, the interested parties, literature about software design and products on the market.

Function

The crossing designer is a support tool for breeders to help them during the process of making crosses. The making of crosses is an important step within the breeding process, because successful offspring depends on the combination of parents. In order to create a successful crossing designer it is important to understand what a breeder does to make crosses. The process of making crosses differs between breeders, because it depends on the type of crop the breeder is working with and which working order a breeder prefers. The crossing designer will be a product, which is useable for all kind of breeders. Therefore it is important to find out the main workflow of the process of making a cross and to find out where in this process the breeder needs support.

Task

The making of crosses differs for each crop, depending on the type of reproduction the crop has. Within plant breeding three types of crosses are distinguished; backcrosses, crosses of vegetative reproducing plants and crosses of generative reproducing plants. The breeding of these different types will be analysed, focussing on finding a common process of making crosses.

Breeding of plants with vegetative reproduction.

The advantage of vegetative reproducing crops is that the offspring of a cross is genetically identical to each other and their parental plants. Therefore heterozygote genotypes can easily be enhanced. The breeding of vegetative crops is easier and shorter than for generative crops, because a new variety can already be received after one generation of crosses. The process can be described in three steps (the fourth step makes the crossing process a continuous process):

1. *Goal;* what the breeder has in mind what to achieve with the crosses. Mostly a goal is defined by traits the ‘new’ variety should have.

2. *Plant Material;* with the goal in mind the breeder will select plant material that are most likely to give promising offspring.
3. *Crosses;* from the selected material the breeder crosses the plants which will give in combination the best offspring.
4. *Selection;* the breeder selects within the offspring for the 'best' plants. The breeder can decide to breed further with these plants and then it is comparable to step 2 (selection of plant material) or the breeder has found a new variety (which happens mostly after a couple of generations of crosses).

Breeding of plant with generative reproduction.

The goal of breeding generative reproducing plants is the creation of hybrids. Hybrids plants are heterozygous, what make them for seed companies very profitable because farmers can't use the progeny of the hybrids (because they are heterozygote, progeny will have segregation) and therefore have to buy new seeds each time. Hybrids are based on heterosis[1], which is the improvement of a certain trait in the progeny of crossing two non-relative parental plants. Crossing relative plants give a decrease in quality due to inbreeding, so by introducing a non-relative plant in the population there will be an increase of genetic variations that will improve the quality of certain traits. Creating a hybrid variety takes several steps and plant generations. The process can be described in four steps (the last three steps are split up in plant material selection and the making of crosses, and the making of a test hybrid is an optional step):

1. *Goal;* what the breeder has in mind what to achieve with the crosses. Mostly a goal is defined as traits the variety should have
2. *Create parental plants;* with the goal in mind of the hybrid the breeder has to create two parental plants for the hybrid.
    a. *Plant Material;* with the goal in mind the breeder will select plant material that are most likely to give promising offspring.
    b. *Crosses;* from the selected material the breeder crosses the plants which will give in combination the best offspring.
3. *Create parental line;* the breeder selects plants that are suitable as parents for the hybrids, from these plants the breeder has to make homozygote parental lines, through inbreeding[2].
    a. *Plant Material;* the breeder selects the plant material (offspring) that have the suitable traits for the parental line.
    b. *Crosses;* the selected plant material is crossed with each other to create a homozygote line.

(4). *Test hybrid;* the breeder can make a test hybrid, to check if the lines will give promising results. To make a hybrid variety takes a lot of time and money, and it would be a spill if it wouldn't work out. Therefore a breeder can make a test hybrid, to decide or the project should be continued. Test hybrids are also useful for a project, because it will reduce the amount of parental lines that are developed.

1. *Example of heterosis*
When a father plant with a leaf length of 150 mm is combined with a mother plant with a leaf length of 200 mm the expectation is to get a progeny with a leaf length of 175 mm. Inbreeding decreases the quality of the genes and could even result in a progeny with a leaf length of 100 mm. Heterosis is when non-relative parental plants are used. It could improve the genes and the result is that you will get a progeny with a leaf length of 250 mm.

2. *Inbreeding:* crossing relative plants with each other, to reduce genetic variation. This results in homozygote lines when only plants with certain traits are crossed with each other (rules of Mendel).

a. *Plant material;* the breeder selects the parental lines, which has to be crossed. These are the still developing parental lines, and aren't homozygote yet.
b. *Crosses;* the selected parental lines are crossed, what will give the test hybrids as a result. The test hybrid will be analysed with the goal the breeder has set.

4. *Hybrid;* the breeder will cross the 'developed' parental lines (homozygous lines) with each other to create the hybrid offspring, and will be analysed to determine if the goal is reached.
    a. *Plant material;* the breeder selects the parental lines, which has to be crossed. These are the developed homozygote parental lines.
    b. *Crosses;* the selected parental lines are crossed, what will give the hybrid which will hopefully match the goal.

Backcrosses

The backcross is a type of cross that is used for vegetative and generative reproducing plants. Backcrossing of plants is more common for generative reproducing crops than for vegetative reproducing crops. The goal of backcrossing is to insert one favourable gene from a plant (mostly a wild relative) into another plant (mostly a cultivated variety). During backcrossing the plant is crossed with a wild relative, and from the offspring the plants with the favourable trait are selected. The selected plants are then crossed 'back' with their relatives of the cultivated variety. They are crossed back for multiple generations until they are genetic the same as the cultivated crop, except the gene they want to have from the wild species. Backcrossing is a constant process of selecting plants and cross them with their relatives. The process can be described in four steps (the last two steps will be repeated, until there is no segregation within the offspring):

1. *Goal;* the breeder has in mind which trait should be introduced in a cultivar. The goal is defined by an existing variety and the missing trait.
2. *Plant Material;* with the goal in mind the breeder selects plant material. For the first cross the breeder selects a wild relative that has the favourable trait and selects the cultivar to cross with.
3. *Selection;* The breeder will select the offspring, which has the trait of the wild species and is most similar for the other traits to the cultivar.
4. *Crosses;* the breeder will cross the selected plant with the cultivar.

Conclusion

Analysing the different processes of the three types of crosses, there is found a common way of working. This common way of working should be the basis of the crossing designer, so that it supports the different kinds of breeders. The structure of the process of breeding is divided in 4 main functions *(figure 2)*.

1. *Set goal;* the breeder will set a goal, in a goal the breeder defines what to achieve with the crosses.
2. *Activities;* the breeder will define how to achieve the goal. The breeder has to choose what type of crosses needs to be made. The term 'activity' is new, but it includes the different types of crosses (developmental crosses, back crosses, inbred crosses, line crosses, test hybrids the breeder can make and where in the breeding process the breeder is in relation to the type of cross which is made.
3. *Plant Material*; with the goal in mind the breeder will select plant material that are most likely to give promising offspring.
4. *Crosses*; from the selected material the breeder crosses the plants which will give in combination the best offspring.

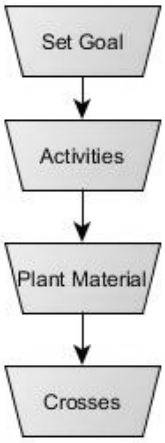


Figure 2. Process of making crosses.

Breeder Support

The structure of making crosses, and the crossing designer working process should be is defined. The crossing designer is a tool, which will support breeders during the making of crosses; it should not take over the breeder's job of making the crosses. Therefore it is important to know where the breeder needs support during making crosses. The activities the breeder does during the four main steps of making crosses should be defined further. By doing interviews with breeders[1] these activities should be specified and there should be find out where those breeders could use support.

1. Appendix III, Interviews

Goal

Defining goals isn't a uniform process within breeding and depends on the classification of crops where is breed for within a company. Breeding can be done for families of crops (e.g. cabbage), different crops (tomatoes or carrots) or segments within crops (e.g. chips potatoes, fried potatoes or salad potatoes). For the different classifications the goals are focussed on different traits. Although these differences the goals have in common that they are defined by traits and tell something about what the breeder wants to achieve with the offspring.

In bigger companies goals are set together with the marketing department, the goal is a translation of what the market wants and what the breeder should create. During the creation of a goal the breeder will set two types of information, basic information about the goal and information about the properties.

1. *Basic information;* what is defined, as basic information of a goal, is the information that should be set for each goal. Breeders all have their own set of basic information, and in the crossing designer the breeders should be able to create their own set of basic information. Basic information mostly includes:
    a. Name of the Goal
    b. Description of the Goal
    c. Crop type
    d. Market type[1]
    e. Market country[2]
    f. Date[3]
    g. Breeder
    h. Location[4]
    i. Notes

2. *Properties;* are almost similar to traits of plants with a value. A goal can be defined in those values. The data in E-Brida about plants (the pedigree items) are linked to properties and have the belonging values. E-Brida contains property sets, which are sets of properties grouped together, because these properties are related to each other and are therefore easier to pick and search within. To define the properties there are two steps, the selection of properties and set a value for the properties.
    a. *Select properties;* the breeder will select from the properties which are available for the crop he wants to set. Therefore the breeder wants to know which properties are available. The breeder selects the properties, which need to have a specific value to achieve the goal. Plants have a lot of properties, but sometimes it doesn't matter what the value for a property is and then the breeder will not select this property.
    b. *Set properties;* the breeder will set the value for the properties which are selected. Therefore the breeder set the value for what he wants to achieve with his crosses. The values can be different (text or numeric) this is all defined for each properties in the E-Brida data storage and should be the same in the crossing designer.

1. *Market type;* for which market the breeding is done for.
2. *Market country;* for which country the breeding is done for.
3. *Date:* begin and expecting end date
4. *Location:* where the breeding takes place

The results of the interviews[5] showed that some breeders would like to give an importance value to properties, because it will aware the breeder of which properties are specific for achieving the goal and which properties will give extra value to your plant besides the goal. The results of the interviews also showed that some breeders thought that an importance value would be useless. These breeders say that each property is important otherwise you would not take it into account. Other reason for not having an importance value is that in most cases of making crosses there are too many cross opportunities and there shouldn't be compromised on properties and their values. Therefore there should be an optional c, set importance value, for setting the properties.

5. Appendix III

During the interviews also the possibility of setting sub-goals came forward. Sub-goals are smaller goals within a main goal, which differ from each other[1].

To set goals isn't something where breeders need support with, but getting support would help them in working more orderly. During breeding there is a lot of data, and by working with goals these data will be more useable later, because the goals explain why certain crosses are made. Most breeders skip defining a goal because it is time consuming. With the goals in the crossing designer the breeder is forced to make goals which will save the breeder in the end time when new crosses has to be made because the data are ordered and contain more information.

1. *Example of subgoals*.
   A breeder wants to have Resistance C in his roses then his main goal will be getting Resistance C in roses, but he wants to do this for his red, orange, yellow and pink roses. Then the colours of the roses are the subgoals.

Activities

Activities are the different crosses a breeder can make to achieve the goal. Especially breeding of generative reproducing plants the breeder has to make a lot of different crosses after each generation. The type of cross depends on the results of the previous cross. All the crosses that are made do have the two step structure of selecting material and select the cross. Although these steps follow each other up, in reality a lot of those steps are taking place at the same time. Therefore the breeder is making different crosses at the same time to achieve the goal. It is important to manage those activities and separate them from each other because the crosses are done with a different purpose but al to achieve the same goal. Management of the data activities makes sure that data can be exchanged between goals and it helps in analysing the goals. Activities include the different types of crosses:

1. *Developmental cross;* these are the most common crosses and the crosses which are the reference point for the crossing designer. Developmental crosses are the first crosses breeders make in order to achieve the goal. With developmental crosses plants with favourable traits are crossed with each other to get offspring with those traits. Breeders can do multiple developmental crosses and can use offspring in the next round of developmental crosses.
2. *Backcross*[2]*;* during a backcross the offspring of a developmental cross is crossed with one of the parental plants. This will be done for some generations (only the offspring with the favourable traits will be crossed back), to create a plant identical to the parental plant except for the trait that is inserted by the other parental plant. During backcrosses a breeder wants to know how many generations of backcrosses are made, to decide or all unwanted genes from the other parent are out of the genome of the offspring. A backcross is a repetitive cross, because the parental plant stays the same and the other plant is the selected offspring of the previous cross.

2. Page 11,

3. *Inbreeding;* with inbreeding the breeder wants to create homozygous lines, and will cross selected offspring from a developmental cross with each other. As with the backcross the breeder select every generation the offspring that match to the goal and crosses these plant with each other. The breeder is therefore interested in which plants are selected from the offspring to be used for crossing and how many generations of breeding are made to determine if the line is already homozygous.
4. *Line cross;* a line cross also includes hybrids and test hybrids. With a line cross two plant lines are crossed with each other. In this case the breeder isn't interested in single plants but in the properties of the line. The offspring of line crosses are not scored individual but as a group of plants.
5. *Selfing;* to create homozygous plants, the breeder can self some plant species. Some plant species have the ability to fertilize themselves. From the offspring the breeder only has to select the plants conform the goal and self them. The breeder is interested in how many generations of selfing are made, to decide whether the plant is homozygous.

Within a goal the breeder can do the different crosses also for different purposes, then these crosses are different activities. Therefore it is important that the breeder will set some information about the activity, to understand the purpose of the activity.

a. Name of activity
b. Type of cross
c. Description of activity
d. Location
e. Date
f. Breeder
g. Note

1. Appendix III

During the interviews[1] the breeders pointed out that they would like to have support in making a general breeding programme, which means that they want to plan two steps (crosses) ahead, from the crosses that are made now. Planning and ordering activities should help the breeder, because it will show the breeder what already has done and where to work further from. The activities are linked to group of plants which are in the field, these plants are crossed, grown or selection within the group of plants takes place. By linking the information of the status of the plants in the fields to the activities in the database, the database can inform the breeder about the status of the activity and warn the breeder when next steps has to be taken. Integrating the fieldwork of the plants with the database also can save the breeder time. Selfing, inbreeding and backcrossing have a repetitive step of making crosses with selected material. This material is already selected in the field, and not as for other crosses selected from a database. Therefore the step of selecting material can be skipped, but the selection of which cross is made not. During the interviews most breeders said that they would like to have an overview of all the possible crosses before deciding which one will be made.

Plant Material

To make a cross the breeder first has to select plant material that should be crossed. For the inbreeding, backcross and selfing the plant material is the selected offspring and therefore this step of selecting plant material can be skipped, because the material is already selected. Selection of plant material for line crosses will go identical to the selection of plant material for developmental crosses, but for developmental crosses there is looked for individual plants as for line crosses there is looked for lines of plants. Selection of plant material will be done through searching for suitable plants material in the E-Brida database. Therefore the breeder needs the database of E-Brida as input for plant material. The selection of plant material can be described in three steps.

1. *Filter;* the breeder has to select plant material from the E-Brida database to make crosses. The crossing designer needs to support the breeder in finding the most promising plant material in the database. The database has a lot of plant material, but the breeder wants to find the material that is useable to achieve his goal. The breeder has to set a filter to define what material is looked for. The filter includes two types of information, basic information and property values.
    a. *Basic information;* this information is the information of the plant material that has nothing to do with the genetic information of the plant material. Basic information is the information, which is available for each plant material. The company defines this information with the system settings. Basic information is:
        a. Name
        b. Pedigree Number
        c. Variety
        d. Year
        e. Type of cross
        f. Location
        g. Stock value
        h. Lot status
    b. *Property values*[1]*;* is the information of the properties of the plant material. The breeder wants to filter material for certain properties. Therefore the breeder has to define the filter criteria of these properties. To define the properties the breeder is interested in the properties that are set for the goal and the values of the properties.

    The breeder has to decide which information to set in the filter to find plant material. There are a lot of filter options but the breeder has to decide which one to use. When a breeder has set a filter it must be still possible to change it, because of the filter results. The breeder can make the filter more specific to get less filter results, or make the filter less specific to get more filter results. In the interviews breeders said that they want to save the filters, because they want to use the same filter another time.

1. *Property values* are things like leaf colour, leaf length or presence of resistance and are traits of the plant. In the filter the breeder has to set what trait and in which appearance the plant it should have. For example, colour: red.

During the selection of plant material, first plant 1 is selected and then plant 2, because the choice of plant 2 depends on the properties that plant 1 has. With hybrid crossing parental plants should have contradicting traits and therefore plant 2 is selected on having contradicting traits of plant 1. For crosses where a certain trait should be inserted in a plant dominancy of genes should be taken into account by selecting plants. Dominant traits are already feasible when only one gene is present in the genome of the plant. Therefore it is sometimes hard to set a filter because only one of the two parents needs to have the trait.

To deal with the fact that the parental plants depend on each other, the filter needs to be adaptable. The filter should change the setting for searching plant 2 to the properties of the selected plant 1. Therefore the breeder has to set the rules for these properties to make sure the filter can adapt. These rules can be defined as inheritance rules[1]. Inheritance rules of a plant can be set with 7 steps that will cover all possible rules and combinations. This system should be included in the crossing designer to make sure breeders can set inheritance rules.

I. Plant (plant 1, plant 2, father, mother)
II. Function (=, >, <)
III. Value (multiple selectable)
IV. Relation (and, or, if, other)
V. Plant (plant 1, plant 2, father, mother)
VI. Function (=, >, <)
VII. Value (multiple selectable)

1. *Example of inheritance rules.* To get offspring with leaf colour red at least one of the parental plants should have the leaf colour red. With the inheritance rule is can set as: plant 1 = red or plant 2 = red

2. *Select Plant1;* the breeder has to select the plant material. In some cases the breeder will select the parental plant separately from each other (e.g. mother and father plant). Therefore there should be the opportunity to select them separately from each other. The selection of plant material 1 can be done, by using the filter on the E-Brida database. Besides the material that will come forward by using the filter, the breeder also wants to see the material that has been labelled in the field as interesting. The integration of the fieldwork and the database is important in this case as well. From the plant material that is filtered or described as promising the breeder has to select the material to work further with. Therefore the breeder wants to compare the property values of the selected material with each other. The breeder must be able to order the material by property, to create a visual comparison that is useful.

Besides the property values there are other things that should be taken into account when selecting plant material. These things should be visible in the crossing designer during comparison of the plant material.

a. Pedigree tree
b. Lot tree
c. Property values
d. Photo
e. Goal properties

The plant material that the breeder selects is placed together and forms a material list, which is comparable to a pedigree set in E-Brida. In this list all the selected material will be placed. It is important that this material list will get a name linked to an activity and a goal.

3. *Select Plant 2;* within breeding plant 1 and 2 are usually selected separately from each other, because the traits of both plants together should give the most promising offspring. For the selection of plant 2 information of plant 1 is needed, the filter for plant 2 should be adaptable to the traits of selected plant 1. This can be done with the use of inheritance rules[1]. The breeder should be able to select a plant 1 and filter for a plant 2 confirm the inheritance rule. In this case the breeder needs to know which plant material is already selected, and for which properties to search for in plant 2. It would be nice if the system could adept the filter confirm the inheritance rules for the search of plant 2 for a selected plant 1.

1. Page 17

From the filter results the breeder is able to select plants and make a separate material list. This is a material list for plant 2, which is specific for a selected plant 1. In the material list that is created should be noted that the plant 2 is specific for the plant 1.

To select plant 2 from the filter results, the breeders wants to have the same information as he has with the selection of plant 1, but also wants the properties of plant 1 wherefore plant 2 is selected. The breeder wants to compare the properties with each other to see if it will give promising offspring.

During the selection of the plant material, filters are created to search for plant material that will give promising offspring to achieve the goals. Filters are created and saved as part of a breeding activity. There are lists of plant material made as result of using the filter on the database. A list of material can exist out of one list of plant material or two lists of plant material. When there are two lists there is a list of plant 1 selection and a list with plant 2 that matches plant 1.

Crosses

The previous steps have all helped to find the parental material that would give the most promising crosses. After selecting the plant material, the possible crosses can be created and the breeder can decide which crosses to perform. In most cases breeders want to make a lot of crosses, but space is limiting because of the costs. Therefore the breeder has to select those crosses, which are most promising to perform. The selection of crosses can be described in three steps.

1. *Create crosses;* the selected material can be find back in material lists, to create crosses the breeder has to select the material list that will be used in making crosses. The material lists that have separate material lists for plant 1 and plant 2, will only create crosses for the plants that are selected for each other. Material lists which only have 1 list of plant material, can be crossed with another list of plant material or the plants within the list are all crossed with each other. All these possible crosses should be placed in a scheme to give an overview to the breeder of all possible crosses. The breeder should be able to use multiple material lists in the crossing scheme. For some plant species there is a difference between father and mother plants. To generate possible crosses the crossing designer should know which plants are fathers and mothers. So the crossing designer needs to have a possibility to point out father and mother plants. The crossing scheme should give an overview of all possible crosses with the selected material. It is important that the breeder can save the schemes and therefore the scheme should get a name and linked to a goal.

2. *Compare crosses*; all the possible crosses are created from the selected material and placed in a crossing scheme. In the crossing scheme the breeder wants to have an overview of all the possible crosses and the important information about the possible crosses. Important information about the possible crosses is information that effects the decision whether a cross should be made or not.
    a. Cross made before
    b. Cross selected before
    c. Available plant material
    d. Family relation
    e. Comparable cross have been made

    This information helps the breeder in deciding for most crosses whether they should be made. As said before breeders have in most cases too many possibilities to cross, by comparing the possible crosses the breeder tries to find the most promising crosses. The important information already helps the breeder in eliminating most of the crosses. If a cross is made before the breeder would like to know the results of the cross and if a cross is generated before the

breeder want to know for which project and the reason why it is selected or not. Information about the family relation of the plant with other plants can help the breeder in finding promising crosses. Breeders try to prevent inbreeding, because it will give a decrease in genetic variation and have a negative influence on the quality of the genetic material, therefore family relations between plants are important to know. Family relations also help in predicting whether a cross is promising. When comparable relatives of both plants have been crossed before the results of that cross can give the breeder information about the possible outcome about this cross. For the breeder it is important to know if the plant material of a cross is available, otherwise a cross can't be made. In some cases the breeder can buy the plant material or grow the material, but the breeder should know it early enough to arrange it.

For some crosses the breeder needs more information on the properties to decide or the cross is promising. In some cases the breeder will compare the properties of the two plants with each other, and decide or the cross will give promising offspring.

3. *Select crosses;* during the comparison of the crosses the breeder can decide or a cross will be made. Important is that the breeder could add a note to a cross with the reasoning why it is made or not, to make sure that when a cross is generated later again the breeder understand what has been done[1]. During the comparison the breeder has to select crosses that should be made. The selected crosses will form a list of crosses that will be made, named a cross list. The breeder should be able to change the cross list by adding and deleting crosses from the list and by adding crosses from other crossing schemes to the cross list.

1. Page 19

When a cross is placed in the cross list, the amount of plant material of the plants of that cross will change. These changes in quantities of plant material must be visible in the crossing scheme as well, so that the breeder has accurate information on whether a cross is possible. When plant material is limited breeders have to select carefully which cross they want to make, therefore it is important that the crossing scheme makes a difference between the crosses that are not available because there is no plant material and the crosses that are not available because the plant material is used in other planned crosses. With this information the breeder can compare the cross and choose the cross that is more promising. The breeder should therefore also be able to deselect crosses.

Not all types of crosses have the steps of selecting material and selecting crosses. For the backcross and the selfing the breeder wants to select all the possible crosses of the plant material selected in the field. The crossing scheme still can be generated but it will serve as an overview for the breeder of the crosses that will be made. The breeder should be able in these cases to select all crosses at once.

The cross list is the input for the other breeding operations of E-Brida. The cross lists include planned crosses, and should be confirmed by the breeder before they are made and new pedigree items are generated. After confirming the crosses can be used in other breeding operations.

Conclusion

The 4-step structure of the crossing designer has been further defined, by explaining the function of the crossing designer in these steps. The crossing designer is a support tool for breeders in finding promising crosses to achieve breeding goals and to record data during the making of crosses. The crossing designer will help in finding possible crosses, but the breeder has to give the input of finding the possible crosses and decide which crosses should be made. Supporting the breeder in recording the data more properly, by setting goals and making activities will help in finding the most promising crosses.

Conclusion

The main function of the crossing designer is supporting all kind of breeders during the making of crosses. The making of crosses can be explained in a 4-step process, which will be the structure of the crossing designer; goals, activities, selecting plant material and creating crosses. Within these steps there are different system functions that will support the breeder through the steps. The back end function of the crossing designer is that data are used and saved more orderly, and the creation of crosses, which will be the input for the other breeding operations of E-Brida.

Stakeholders

The main function of the crossing designer is to support breeders during the making of crosses, therefore it is important to know who those breeders are and which breeders are going to use the crossing designer. During the interviews[1] with the breeders there has been analysed who those breeders are and looked at their interests in the crossing designer. Besides the breeders there are also other people who have interests in the crossing designer, they may not use the crossing designer but their relation with the crossing designer makes their interests also important for the success of the crossing designer. Therefore it is important to know what their interests are in the crossing designer and how these interests can be taken into account during the design of the crossing designer.

1. Appendix III

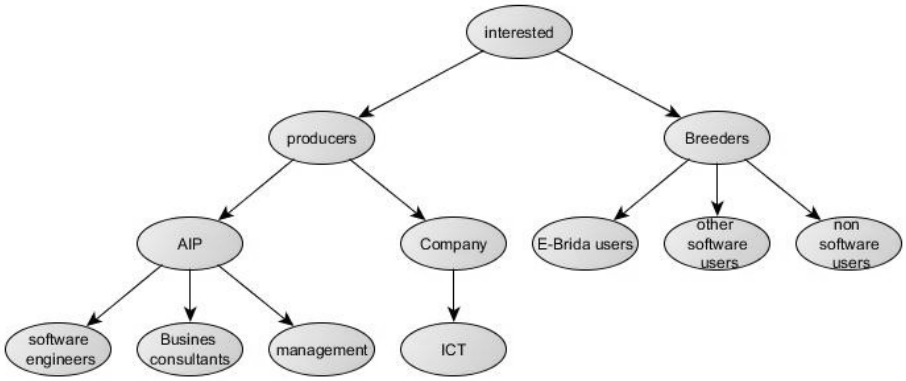


Figure 3. Schematically overview of the stakeholders of the crossing designer.

The interested parties have been divided in two groups the people that will work with the crossing designer, which are the breeders, and the people that take care of the crossing designer, which are called the producers *(figure 3)*.

The producers of the crossing designer can be divided into two groups; AIP, the company that creates the crossing designer, and the company that bought the crossing designer, specifically the ICT staff of the company because they will buy and maintain the crossing designer within the company. AIP has 3 different groups of people with interests; the software Engineers of AIP who will built the crossing designer, business consultants who have to sell the crossing designer and the AIP management which invest in the crossing designer. The interests of the AIP management and business consultants are almost similar and will be described together.

The breeders are the main target group of the crossing designer. Within the group of breeders there is a difference between breeders that already use E-Brida, breeders that use other breeding software and breeders that do not use any breeding software. It is important to be aware about these three groups of breeders because their interest as breeders may be the same, but there input during the design of the crossing designer can be different. Breeders that already use software during breeding activities already experienced the advantages of software use during breeding and have a better idea of how they want the software to help them. Breeders that haven't use software during breeding activities are more hold back about using software to support their work. The crossing designer will be part of E-Brida and breeders that already use E-Brida can imagine better the advantages and possibilities of a crossing designer in E-Brida than breeders that use other software. All the 3 types of breeders have been interviewed in order to get information about all possible users of the crossing designer.

Breeders (main users)

The breeders are the primary users of the crossing designer. As described before there can be made a difference between the breeders on their software usage. The interests of the three groups are the same and therefore not described separately, but the input for ideas about the crossing designer can differ between these groups. The crossing designer will support the breeder during the making of crosses and therefore it should be adapted to the user's needs. Breeders are people who are educated on WO or HBO level, and already have some working experience within the plant breeding sector and are therefore mostly older than 30 years. Breeders are people who have a practical attitude and like to work with plants and in the field. The way of working between breeders differs a lot and depends on the crop and the company where is worked for. For each type of cross it differs how many crosses each year can be made, and in which period of the year they should be made. Most breeders work alone during the making of crosses, depending on the size of the company the crosses are discussed with other breeder before they are made. A lot of breeders make use of Excel[1], they use Excel spread sheets to share data with other breeders. A lot of breeders that already work with breeding software still make use of Excel as well. Therefore it is important that data can be exchanged between Excel and the crossing designer. In most companies the crossing program is made at the office with the results of plant selection and will be preformed afterwards, but in some cases crosses are planned and made in the greenhouse or the field directly during the selection of plants. Most breeders described the making of crosses as time consuming during the interviews[2]. The most time during the making of crosses takes the looking up of plant material and the history of the plant material comparing with other plant material.

1. *Excel* is a spreadsheet application developed by Microsoft.

1. Appendix III

Main interests

- Making of crosses
- Filter for plant material
- Set a goal
- Useable through the whole year
- Find promising crosses
- Avoid making the same cross
- Compare plant material properties with each other
- Knowing where you are in the breeding process
- All data together
- Import and export of data in and from Excel
- Add notes to crosses
- Clear records of activities
- Add notes
- Making of draft crosses
- Available plant material
- Time saving

Software Engineers

The software engineers are the people at AIP who will develop the crossing designer software. These people are qualified software engineers, and work in teams to develop and maintain software. On the moment at AIP a switch is made within software development from Windows-desktop software[1] to Web-based software[2]. All software engineers within AIP have the capacity to make web-based and windows-desktop software. Within AIP there is a team that contains software engineers specialised in E-Brida. As the crossing designer being part of E-Brida, these people will probably work on the development of the crossing designer. The main discussion point for the software engineers about the crossing designer is in which environment the crossing designer should be built. E-Brida is windows-desktop software, and if the crossing designer will be part of E-brida it would be logical to make windows-desktop software. Although E-Brida is windows-desktop software, AIP expects that in the next 10 years it will be rebuilt to web-based software. These plans make it more interesting to start building the crossing designer as web-based software, because otherwise it has to be rebuilt in at least 10 years. For this project AIP decided to make a web-based software of the crossing designer, because web-based software can easily be built as windows-desktop software but the other way is harder.
Besides building the crossing designer the software engineers will maintain the crossing designer. In the beginning stages of the crossing designer's existence the engineers will mostly concentrate on adding extra functions to the crossing designer and repairing bugs in the system. In the later stages when the crossing designer is fully working, the engineers will mostly make small company specific changes to the crossing designer. The crossing designer will never be finished, because technology moves forward and the crossing designer has to adapt to it. For the software engineers it is also important that they always can improve the crossing designer so they can maintain their job.

1. *Windows-desktop software* is a computer program that runs locally on a computer device, such as desktop or laptop computer with a windows system.
2. *Web-based software* is an application that is delivered to a local device over the internet from a remote server, such as internet browsers.

Main interests

- Easy to build
- Build in steps
- Basic structure which can be expanded with extra functions
- Functions must be built as plug-ins
- Companies can make the crossing designer specific for the company with plug-ins
- Plug-ins are easy to change
- Minimum maintenance
- The crossing designer should make use of as many possible aspect of E-Brida
- Continuous development of the software

AIP

AIP is the company that will bring the crossing designer on the market. Within AIP there are the software engineers, which interest has been described already, the business consultants and the management. The business consultants and the management have shared interests, which are the sale of the crossing designer. To sell the products of AIP, and thus also the crossing designer, demonstrations of the products are given at interested companies to persuade them of the advantages of the software. Therefore the crossing designer should be useable at different locations. Demonstrations of the software are mostly given at the location of the interested company by the business consultant. The business consultant will prepare a demonstration of the software by making use of examples that are recognisable for the interested company[1], what takes more preparation time but it will results in a higher turnover. A demonstration takes approximately an hour and explains the main functions of the software. In that hour a company has to decide if the product is something for them. They will make a decision based on what they have seen, and therefore it is important that the crossing designer looks attractive. When a product is sold, AIP still has to implement the product at the company. During the implementation of the product, AIP will install the software at the company, instruct the people how to work with the software and support the transfer of the company's data to the new software. The implementation takes around one or two weeks depending on the size of the company and which software will be implemented. AIP wants the crossing designer to be part of E-Brida, and sold as one product. Therefore it should not be a separate function, but part of E-Brida to avoid requests for separate sales.

2. *Example of a demonstration adapted to the interested company.*
When a business consultant will give a demonstration of E-Brida at a company that breeds apples, the data to demonstrate E-Brida with will be about apples. The possibilities of E-Brida will be shown with the use of apples. Using the data that are recognisable for the interested company, will give them a better idea of the advantages the software could have for them.

Main interests

- Easy to demonstrate the software
- Offline useable
- Visual advantages, by looking attractive
- Easy to explain
- Wizard instruction function
- Implementation time of 1 week
- Part of E-Brida
- Profitable

Conclusion

There are three main stakeholders which have different interests but a common goal; they all want a good working software application that will support the breeder during the making of crosses. For the breeders it is most important that they will create more successful crosses by using the crossing designer. The software engineers want a product, which can be built and maintained easily and AIP would like to have a profitable product to keep the company running.

Software Design

The crossing designer will be a software application, which is part of E-Brida. In this assignment the software structure will be designed and part of the user-interface. Software and user interface design have different design principles than product design. Software design and user interface design is relatively new, this because the first computers where brought on the market in the 70's. During the design of the crossing designer the principles of software and user interface should be taken into account, which are found in the literature about the history of user interface design.

User-interface evolution

The last 30 years user interfaces have been developed enormously. There can be three types of user interfaces distinguished, which have followed each other up during their development[1].

1. Rogers et all. , 2007

1. 1980's interfaces
    a. *Command interfaces;* the computer was controlled by giving commands. The commands where typed by the user or by pressing certain control combinations on the keyboard.
    b. *Windows, Icons, Menus and Pointing;* modern user interfaces still use this type of interface. The communication with the computer is done with elements that are displayed on the monitor, which can be selected by the user. Modern user interface have further developed elements and selection processes.
2. 1990's interfaces
    a. *Multimedia;* different kind of media are combined in one user interface (such as graphics, text, sound and animation). These media are connected with each other by different interactions.
    b. *Virtual reality or virtual environments;* are graphical simulations by the computer, which give the user the idea that there is movement in a real environment.
    c. *Voice controlled interface;* the user can speak to the computer and the computer can translate spoken language into computer language. It isn't possible to have conversations but it can be used to give commands.
    d. *Stylus controlled interface;* the use of stylus makes it possible to write and draw on a tablet and make a digital drawing. The computer will display the movement of the stylus on the monitor.
    e. *Movement controlled interface;* the computer can register movements of the user, which can be used to let the user control the computer.
    f. *Touchscreen;* the user can control the interface on a monitor with his fingertips.

3. 2000's interfaces
    a. *Mobile interfaces;* are interface for mobile devices that are usually when users are on the go. Mobile devices have different user interfaces because the monitors are a lot smaller of size. The interfaces have menu structures for which different control opportunities are possible such as touch control or stylus control. Mobile interfaces have two possibilities to enter text; by a numerical keyboard or a letter keyboard. The user interface can have special functions (like T9) to make the use of numerical keyboards easier.
    b. *Multimedia interfaces;* are the extended version of multimedia, they combine touch, sound, speech, stylus and movement input to control the interface. It is possible to use multiple types of input and get multiple types of output on the same moment.
    c. *Shared interfaces;* are interface which can be controlled by different users on the same moment. Smart boards are a well-known example, which are used for educational purposes.
    d. *Augmented interfaces;* these interfaces combine computer models with reality. In different work fields they already make use of augmented interfaces, like projecting satellite images of the weather on maps in explaining the weather forecast.
    e. *Portable interfaces;* are carried by the user, like glasses and watches. They can measure body activity and can also have integrated function such as a radio.
    f. *Robot interfaces;* are interfaces to make the control of robots easier. Joysticks, keyboards, cameras and sensor controls are combined to control the robot more carefully.

Software design principles

Literature describes all kinds of guidelines for user interface design. These guidelines are important because they make sure that the system will be useable through the interface, for the users[1]. The design principles that were first proposed are still the base for all other design principles that have evolved. These 4 main principles are[2]:

1. Know the user
2. Minimize memorization
3. Optimize operations
4. Engineer for errors.

These 4 main principles are described as 3 design principle areas, place user in control, minimize memorization and consistent interface[3].

1. Mandel, 1997
2. Hansen, 1971
3. Mandel, 1997

Place users in control

For people it is hard to fully trust a computer or software program, therefore users would like to control the computer to make sure that everything goes well. The user interface should give the user a degree of control, to make sure people trust the software. In the background the computer does the work, and the user has a limited set of tasks that give the feeling that they are in control. An important aspect is that the user is able to use all function within the interface, while in reality the user can't control all the functions of the system, but these function won't be displayed. To place the user in control the following design principles should be taken into account.

1. Modeless; when software uses modeless windows the user is in control, because the user can decide what to do with the window. Modal windows[1] are windows that force the user to supply requested information while all other applications are inaccessible. Modal windows should be avoided where possible.
2. Flexible; allow multiple control input such as mouse or keyboard, and let the user choose which input to use.
3. Interruptible; allow users to change focus or form the program.
4. Helpful; display descriptive messages and text as support for the user to understand how to use the program.
5. Forgiving; provide immediate and reversible actions and feedback
6. Navigable; provide clear and multiple pathways
7. Accessible; accommodate users with different skill levels
8. Facilitative; make the user interface transparent, so that the user has the idea that everything is useable.
9. Preferences; allow users to customize/personalize the interface
10. Interactive; allow users to directly manipulate interface objects.

2. *Example of modal windows* Promopting the user for a file name to open a document.

Minimize memorization

The human memory is limited, and the use of computers can expand the human memory by remembering information and show it when needed. Within breeding a lot of data are collected, and it isn't possible to remember all those data by a breeder. In the past data were written in books to save the knowledge, now a days this is done by the help of computers. The advantage of the computer is that the searching for information will go faster, because the computer will do the work of finding information. To minimize the memorization of the user the following design principles should be taken into account.

1. Remember; don't force the user to keep information in the short-term memory.
2. Recognition; Allow users to find things back by recognition instead of finding back by blank searching.
3. Inform; provide visual clues to the user about what is going on.
4. Forgiving; provide immediate and reversible actions and feedback
5. Frequency; provide interface short cuts, for frequent used functions
6. Intuitive; promote an object-action syntax[3]

3. *Object-action syntax* is an interface interaction model, wherby the user first selects the object and then the action to preform on the object. For example: a user selects a document and then drags it to the correct folder.

7. Transfer; use real-world metaphors or known user interface metaphors in the user interface design.
8. Context; use progressive disclosure, don't overwhelm the user with all functions.
9. Organize; group items and don't present too much information at the same time.

Consistent interface

Consistency in user interfaces is a key aspect for useable interfaces. The major benefit of consistency is that users can transfer their knowledge and understand a new program more easily because of their knowledge on other computer programs. During the interviews[1] breeders mentioned that E-Brida was difficult to understand and hard to explain to new users. Therefore consistency is very important to create a useable interface for the crossing designer. To have a consistent interface the following design principles should be taken into account.

1. Continuity; make clear what the user's tasks are and where in the process the user is.
2. Experience; maintain consistency across the product within the functions, such as presentation, behaviour and interaction of the product.
3. Expectations; present the results from interactions in the same way, so that the user knows what to expect.
4. Attitude; provide the same lay-out all over the user interface to have aesthetic appeal and integrity.
5. Predictable; encourage exploration of the product and other functions by providing information.

1. Appendix III

Conclusion

In the last decade the development of interfaces was mainly focussed on making interfaces even more interactive. The crossing designer is a support tool whereby the interaction of the crossing designer with the user is the support during the breeding process. The interaction is mainly based on data and not on physical interaction. There are possibilities within the crossing designer to make use of interactive user interfaces. With mobile interfaces breeders can make crosses wherever they are because they can bring their crossing designer with them. With the mobile interfaces, the multimedia interfaces come along. Portable devices can be used with different inputs such as touch or stylus. For the crossing designer the shared interfaces are also interesting, because the breeder can discuss with other breeders about which crosses to make[2].

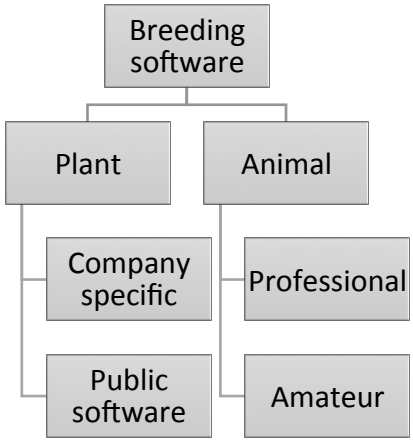
2. Breeders communicate with each other about crosses, to find the most promising crosses.

Analysing the design principles showed the design principles that are applicable and important during the design of the crossing designer.
That the user is placed in control is important for the crossing designer. During the interviews[1] with the breeders the main barrier for breeders to make use of breeding software was that they would like to have everything in control and that they do not trust the computer. For the crossing designer the design principles; modeless, forgiving, helpful, navigable, accessible, facilitative, preferences and interactive are important to take into account. The minimization of memorization is important because breeders have a lot of data and need help in remembering all this information. For the crossing designer the design principles; remember, inform, forgiving, frequency, context and organize are important to take into account. A consistent interface may not look like as an important design aspect, but it actually is because it makes sure the software is useable for users. For the crossing designer all the design principles are important to take into account (continuity, experience, expectations, attitude and predictable).

1. Appendix III

Product research

As software is becoming more and more important in the daily world, it is visible that breeders are making use of software more often to support their activities. (the support of work by software is visible in all kind of branches). To create a successful product, it should exceed existing products. Analysing the current market of software that support breeding activities will show how the crossing designer should differ from the rest. It also can give ideas of how the crossing designer should work and look like. There is no market of products that specifically supports the process of making crosses, therefore the market of products that support breeding activities is analysed. Within this market there are products that also support the process of making crosses. The products that have been analysed are divided in 2 groups and 4 sub-groups *(figure 4)*. The competitor's research is done on software that supports plant breeding activities but also animal breeding activities. Animal breeding software is included because it has a lot of similarities with the plant breeding process. In plant and animal breeding the goal is to select parental material, which will give improved offspring when it is crossed. Within animal breeding software a difference is made between professional software and amateur software, but for the results of this analyse it doesn't matter. The animal breeding software is mainly analysed to get ideas of how the crossing designer should look like. Within plant breeding software a difference is made between company specific software and public software. E-Brida the product of AIP is public software because it can be bought and used by anyone. AIP also collaborate with companies to create tailor made software for these companies. Company specific software is more detailed than public software and not useable for everyone. As the crossing designer will be public software it shouldn't become detailed but useable



gure 4 Division of comparable software

for everyone. Analysing the company specific software will show the difference in detail between public and company specific software.

Plant breeding - company specific software

Most big breeding companies have their own company specific software to support the plant breeding process. It is very hard to get information about their software because it is all company secret. The big companies have specific tailor made software, and smaller companies sometimes create a kind of company specific software. In Excel the breeders make schemes and use formulas to track their plant material, in such a way they do create their own software, by making use of a general software program. In this analyse of breeding software it will not be included as company specific software, it will be considered as a working manner of a breeder. AIP works together with Rijk Zwaan by developing their company specific software. Due to this corporation it was possible to analyse company specific software. There is one interview done with a breeder who had developed his own software for melon breeding, this software was also used in the analyses.

VNG – Rijk Zwaan

VNG[1] is the successor of Rijk Zwaan's company specific software VERA. AIP is developing VNG, which is based on the VERA[2] software, and is highly involved during the implementation of VNG. VNG has a basic structure but has been customised for the different departments (the departments are based on the crop varieties within RijkZwaan). VNG is a data storage programm, comparable to E-Brida. It supports breeders in administrating the data of breeding activities, but it doesn't have something as a crossing designer. VNG can support in some ways the making of crosses, because parental material can be searched for and plant material can be clustered project specific. The main problem users experience with VNG is the filtering of data, and they rather like to export the data to Excel and filter then instead of making use of the filter in VNG.

1. VERA Next Generation (VNG)

2. Veredelings Administratie (VERA)

Melon Breeding

This breeding software is made by Maarten den Hertogh who is a melon breeder at Rijk Zwaan. He has made this software by using Windows Access[3]. The software supports him and the breeders within his breeding team during the making of crosses, by finding plant material with interesting traits. In the programme the breeder can select traits for a plant and select the values for the properties. After selecting the properties and set a value for it the software will search in the plant material database for plants that match the filter settings. The software makes it more easy and faster for the breeder to find candidate plant material for crosses. The software is very easy and basic and is more a help tool during the making of crosses than overall support software for the making of crosses. The search for candidate plant material is where the breeder needs support and therefore the crossing designer should have this function.

3. *Access* is a database management system developed by Microsoft

Plant breeding - Public Software

There are not a lot of software products like E-Brida, public software products that will support breeders during the making of crosses. Comparable products like E-brida are more data-storage software instead of supporting software during the making of crosses. The crossing designer will be something really new, software that supports the making of crosses. The products that are analysed do not have the exact same functions as the crossing designer, they might have some overlapping sub-functions. It is also interesting how these types of software work, in supporting the breeder, to get ideas of how the crossing designer could work or look like.

Verdi – Distel Software

Verdi is a public software and comparable to E-Brida. During the analyses it wasn't possible to actually work with Verdi, but the information about the possibilities with Verdi gave a good idea about Verdi. Distel Software makes software for the agrarian sector and have their own software and collaborate with companies to make company specific software. Distal software is therefore comparable to the company AIP. Verdi is software that supports the breeder during different steps within the breeding process. Verdi has different functions to support the breeder. The breeder can set crossing goals by defining the properties of the offspring to be created. With this information Verdi can select candidate parental plants but the breeder also can search for parental candidates manually. The breeder has to select the plants that could be used in next generations of crosses. In Verdi the breeder can give instructions to carry out crosses, whereby Verdi will create pedigree numbers[1] for the offspring. From there Verdi will also support the other steps of the breeding process such as harvesting and sowing. The offspring can be scored on properties that are set by the breeder. The breeder can compare property scores from different scoring moments of a plant. The breeder can also add photos to the properties. Verdi can create reports and overviews of all the data and place the data in a pedigree tree.

1. A pedigree number is a number that is used as a label for a specific plant.

Labkey selection software – Doriane

Labkey software is used for plant breeding, and is a package software. It is a package software because it exists of different applications. The application supports difference tasks within a breeding company. Labkey selection is an application specific for the breeding of plants and supports the different types of breeding (e.g. hybrid breeding, line selection). Labkey selection has a database with all the plant material and the corresponding genotypes in it. When the breeder is making a new cross he can import the genotypes from the database in his experiment, after selecting the parental plants Labkey selection will automatically create the crosses between the selected parental plants and include the genotypes of the parents in this cross. During the breeding process Labkey selection supports the management of the data, such as reports, labels and working instructions.

The new material is all given a new code and saved in the database. Labkey selection also keeps track of the plant material stocks. For the different types of crosses Labkey selection will give specific support. By selecting what type of cross will be done, Labkey selection will create the crossing process automatically for this type of cross.
Labkey selection is focussed on breeding process management, breeders will create activities in Labkey selection and link crosses to these activities. Labkey selection will support the breeder with the management of the breeding process by providing the information, labels and working instructions for the crosses. It makes sure that when a breeder has set up a cross it will be carried out that way.

Seedorg – Zayintec

Seedorg is a professional software platform developed for plant breeding and vegetal germplasm[1] banks developed by Zayintec. Working with a platform makes it possible that all data can be shared with different users of a team and the data can be modified from different locations. Seedorg has a database for all genetic plant material, which also keeps track of the stock of the plant material. It supports the breeding of hybrid and normal crosses. Breeders can make use of a search engine that works with filter settings to find plant material. This search engine can be used as well for the selection of plant material for the creation of new crosses. Users can send tasks and messages to each other so that they know what everyone is doing, which is important because they are all working in the same environment. Users can export data from Seedorg to Excel to work further with the data in Excel. Breeders can monitor plants and save information of plant material in Seedorg.
Seedorg makes use of a platform, which means that all users work in the same database and environment. The users can communicate with each other through the platform, and directly relate data in their communication. The use of a platform might be interesting for the crossing designer, because it is convenient when people have to work together.

1. *Germplasm* is a collection of genetic resources for an organism.

Agrobase – Agronomics

Agrobase is the breeding software of Agronomics, which has four main functions; compare plant material, analyse plant material, manage plant material and the making of breeding decisions. Agrobase has a database for all the genetic plant material, which also keeps track of the stock of the plant material. The database of Agrobase is a relational database, this means that the genetic material in the database is compared to each other and that the database contains information about the relation between plant material. Breeders also can create breeding programmes in Agrobase, by using the plant material from the database. During the creation of breeding programmes, the breeder gets support with the making of the field planting list and sowing list. Agrobase also generates the labels and reports for the breeding programme. The results of crosses that are made can be analysed in Agrobase. Agrobase helps with making analyses

about regression, correlation, covariance and plant statistics. Agrobase has online tutorials for their software, users can make use of it to understand Agrobase better and make optimal use of all the functions.

Agrobase is a broad type of breeding software, which has most of the supporting functions that E-Brida has as well. Users appreciate the online tutorials that Agrobase has, because it gives them the opportunity to learn and discover Agrobase by themselves. The idea of online tutorials could be used for the crossing designer to support users in learning to work with the software. Current problem with E-Brida is that most users have difficulties with understanding the programme and therefore don't use E-Brida optimally. Online tutorials might help breeders to understand it better and appreciate the software more because they can use it more optimally. Breeders can learn more while working with the software, and people who don't use it as often can refresh their knowledge about the software with the online tutorials. It will be helpful in making the crossing designer user-friendly.

E-Brida – AIP

E-Brida is a software application for plant breeders, which is made by AIP. E-Brida supports the breeding administration of generative and vegetative plant breeding. It is developed in cooperation with breeding companies and the experience created within AIP during the years of making software for the seed and breeding business. E-Brida supports breeders during the breeding process[1].

1. Website Agri Information Partners, 2014

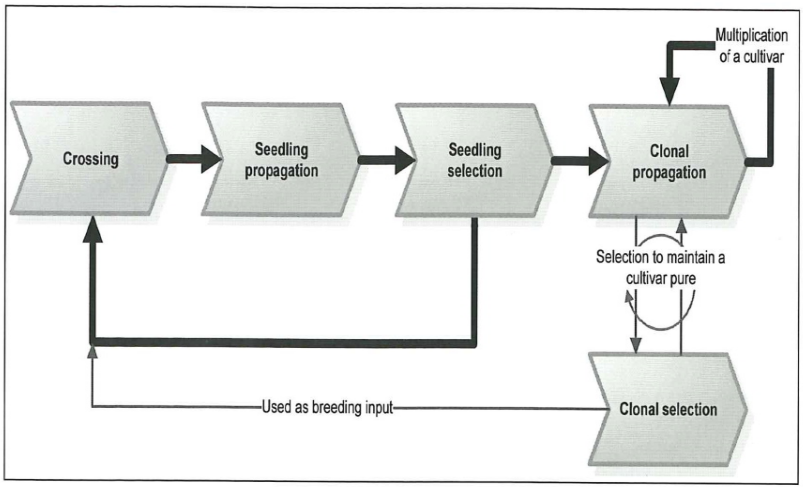


Figure 5. Steps of breeding vegetative reproduction plants (Agri Information Partners 2014).

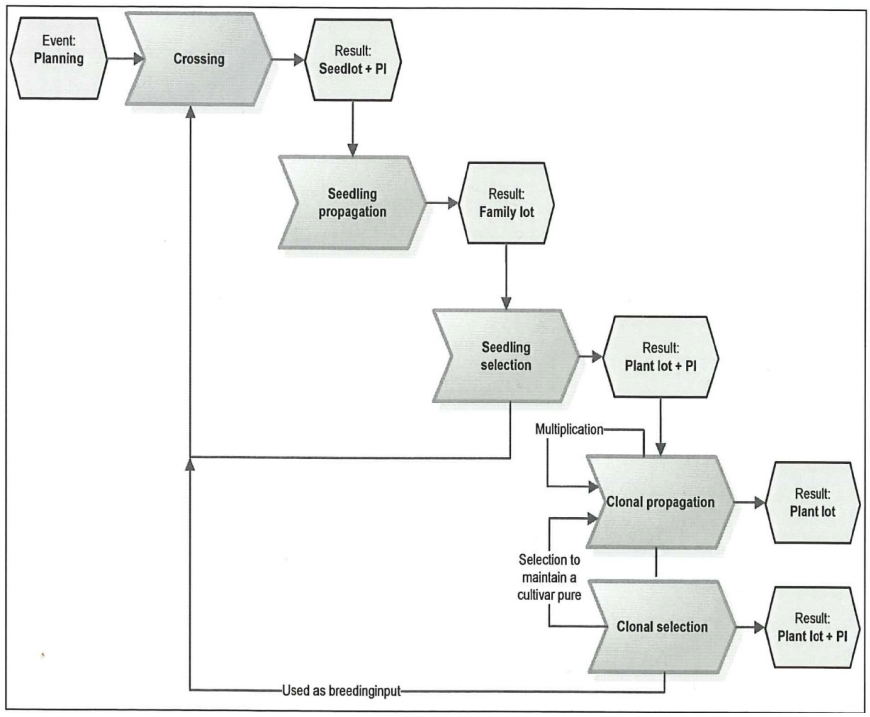


Figure 6. Steps in E-Brida of breeding vegetative reproduction plants (Agri Information Partners, 2014).

The four basic functions of E-Brida are: crossing, selection, trials and observations. These functions support management of the data during the breeding process. E-Brida makes a difference between the process for vegetative plant breeding and generative plant breeding. Breeding for vegetative reproducing plants E-Brida has five main steps; crossing, seedling propagation, seedling selection, clonal propagation and clonal selection *(figure 5)*. These steps can be supported by E-Brida *(figure 6)*.
To make a cross the parental plants are selected from the pedigree book (which is the database with all the plant material in it). The crosses that are made results in seed lots (lots are the physical things, in the case of seed lots the new formed seeds of combining two plants), these seed lots give a new pedigree item (a new plant material, for in the database). These seeds have to be grown what is done with the seedling propagation function in E-Brida. The grown seeds result in family lots (the physical plants grown from the seeds that are produced from the offspring of a cross). The plants are observed on properties and selected by the breeder. The observations are placed in E-Brida and can be used later as information about the plant during the selection of plant material. From those family plots plants will be selected (to use further) which will give selected plant lots, and pedigree items. The plants that are selected will be clonally propagated[1]. In E-Brida all these steps are taken and data will be registered.

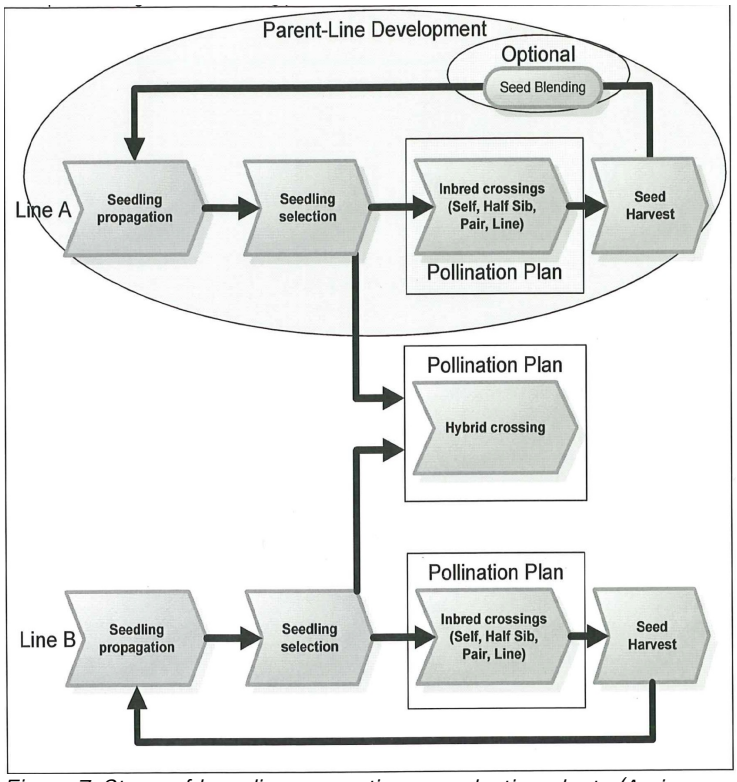


Figure 7. Steps of breeding generative reproduction plants (Agri Information Partners 2014).

Breeding for generative reproducting plants, homozygotes plants are tried to create as parental plants in order to create hybrid offspring. The main difference with breeding for vegetative reproducing plants is the presence of a pollination plan. Another difference is that for generative reproducing plants, clonal propagation isn't possible and therefore clonal propagation en clonal selection are not present as a function. For generative reproducing plants two breeding lines are needed *(figure 7)*. The steps for breeding with generative reproducing plants can be supported by E-Brida *(figure 8)*.

Registration of data, which are maintained or created during the breeding process, can be ordered and sustained. The first steps are almost the same as with the vegetative reproducing plants. Parental plants are selected from the pedigree book, and crossed with each other, resulting in seed lots that will be grown into family lots. Observations of the grown plants can be registered in E-Brida, even as the selection of plants. From this the process will differ from the vegetative reproducing plants. The selected plants and the plant lots are used to set up a pollination plan. A pollination plan will manage the inbred crosses that are made. The inbred crosses will result finally in new pedigree items and seed lots. In the pollination plan the amount of self-pollinating generations are determined, to get a homozygote plant. The homozygote plant material can be used for hybrid crosses or to create new inbred lines. Hybrid crossings results in new pedigree items and seed lots.

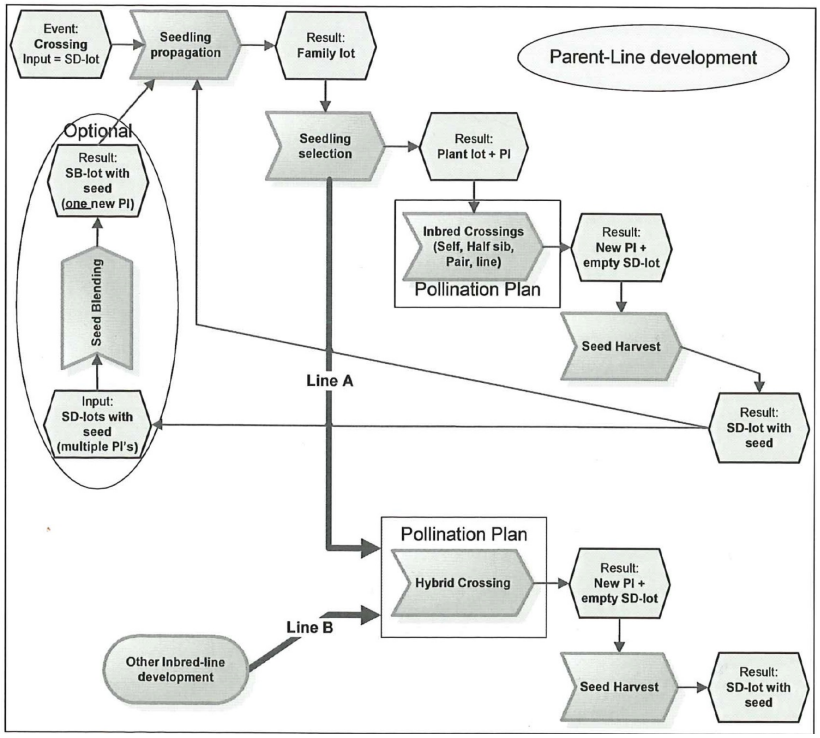


Figure 8. Steps in E-Brida of breeding generative reproduction plants (Agri Information Partners, 2014).

Animal Breeding Software

Animal breeding software is interesting to look at because it is developed much more than plant breeding software. The breeding of plants and animals has a lot in common and therefore animal breeding software is comparable to plant breeding software. Plant and animal breeding are both looking for the best combination of parents to get the most promising offspring. Within animal breeding software, a difference between professional and amateur software can be made. For this research the difference isn't taken into account, because the focus is on how the making of crosses is done in animal breeding and how the software supports that.

Zooeasy

Zooeasy is an animal breeding registration software. This software is designed for different types of home-animal breeding. The breeder can manages pedigree trees, medical information, competition scores and sales data about the animals. In the software the breeder can make crosses of two parental animals by first creating the offspring and then link it to the parental animals. The software will automatically update the pedigree tree. The pedigree tree is a very important aspect of the software because it gives information about the background of an individual animal.
It is interesting that this software doesn't cross parents but links offspring to parents. Zooeasy has the possibility to look for candidate parents with the search engine. The search engine is a filter that can be set by the breeder to find candidate parental animals. The software is very easy to

use because it defines physical individual animals, while in E-Brida the difficulty is that not everything that is defined is physical material. Working with physical material makes it easier for the user to visualise it. The pedigree tree of Zooeasy is a good example for the design of a pedigree tree in the crossing designer, because it contains a lot of information.

IBreed

This is a pedigree and livestock management system for animal breeding. It has a simple database that gives breeders the opportunity to store the data about their animals and find information about the animals. It creates pedigree trees of the animals and gives offspring statistics. Offspring statics tell something about the possible genotype of the offspring, calculated from the genotypes of familiar animals. The software can predict the possible genotypes for the offspring when two animals are crossed with each other. The software creates the genetic information itself by the properties and the values that have been given to the animals.
The prediction of the genotype of the offspring is very interesting for the crossing designer, because the crossing designer supports the breeder in finding parental plants to get a certain type of offspring. In IBreed it is the other way around, two parents are crossed and the genotype of the offspring can be predicted. This could be used in the crossing designer as well as an evaluation tool for the created crosses.

Conclusion

Analysing different comparable products has given new ideas for the crossing designer. Comparable plant breeding software but also animal breeding software is analysed to find new ideas for the crossing designer. One of the main functions for the crossing designer is a filter to find potential plant material to make crosses with. Breeders know what the offspring should look like and know which genes they need from the parents to create this, and therefore it is important that they will find parental plants that will have these genes. Support during the entire process of making crosses is important to make the software useable, breeders like to use one type of software during the making of crosses and want to do everything in it. The crossing designer should have supporting tools but also a database to store plant material data in. The use of online tutorials could be helpful in making the software user-friendlier, because breeders can use the software optimal with the help of these tutorials. A platform has an advantage when there is worked in projects and with multiple people together. The platform makes sure that people have up-to-date information and that everyone is informed about what is going on. Breeders can evaluate potential crosses better because the crossing designer is able to predict the genotype of the offspring. The breeder compares this to the goal to determine the success of the cross. It would be nice if the software could calculate from the family properties the properties of the offspring. This isn't very easy because the inheritance behaviour of most genes is not known yet.

Requirements and Specification

The analyses have given a lot of information about how the crossing designer should look like and work. This information has been turned into a program of requirements and specification for the crossing designer. The requirements are based on the information received during the analyses and mainly on the interviews with the breeders about the crossing designer. The requirements are divided over four categories; usability, system, data and functioning. The functioning is divided in the different tasks the crossing designer has; set a goal, set properties, create filter, select material, compare plant material and crossing scheme.

Usability

1. Crossing designer interface contains only information that is relevant for the crop worked with
2. Crossing designer interface contains functions that are relevant
3. Crossing designer interface shows where in the process the user is
4. The crossing designer should not contain double steps
5. Function keys are used the same in the whole crossing designer
6. Users can use crossing designer individual after a training of 2 days
7. Maximal required steps to insert information is 3
8. The different functions of the crossing designer should be able to be used individual.

System

1. Crossing designer can be used offline
2. Crossing designer can be used on desktop computers
3. Crossing designer can be used on portable devices
4. Crossing designer can be started from E-Brida
5. Crossing designer can be started separate from E-Brida
6. Crossing designer interface is web based

Data

1. Filter setting can be saved
2. Selected material can be saved
3. Selected crosses can be saved
4. Selected crosses can be used as input for pollination plan
5. Crossing schemes can be saved
6. Crossing designer uses the E-Brida database
7. Plant properties are imported from the E-Brida database
8. New property sets can be made in the crossing designer
9. New property sets can be exported to E-Brida
10. Plant material comes from the E-Brida database
11. Data can be exported to and imported from Excel.
12. Data can be printed
13. Selections of plants in the field are linked to the E-Brida database

Functioning

1. Crossing designer can be turned on and off
2. User should be able to switch between functions
3. Crossing designer should start up in 1 minute

Set a goal

1. Users can give goals a name manually
2. User can add a description to a goal
3. User can set properties
4. Crossing designer user interface shows crossing activities within the goal
5. User can create a new goal or work further within an existing goal
6. User can link data (filter, material, crosses and crossing schemes) to each other
7. Goals can be changed
8. User can set at least 10 different subgoals
9. Crossing designer interface of a goal contains a button to create a new activity within the goal.

Set properties

1. User can select properties from E-Brida
2. User can create new property sets
3. User can set the value for a property
4. User can set different values for a property for different sub goals
5. User can set importance value for a property.

Create filter

1. Filter contains the set properties
2. Filter user interface shows the properties of the goal
3. User can set different filters within a goal
4. Filters are changeable
5. User can set inheritance rules for a property
6. Filter can be divided in filter for plant 1 and plant 2
7. Filter on the importance value of a property
8. Filter remembers the inheritance rules
9. Properties can be added and deleted from the filter
10. Crossing designer interface contains opportunity to save filter

Select material

1. Can filter for plant material in the E-Brida database
2. Crossing designer interface contains opportunity to select or create a filter
3. User should be able to change the filter without losing selected plants
4. Crossing designer interface contains opportunity to order the filtered material

5. User can select at least 20 plants together
6. User can select plants individual
7. User should be able to add notes to plants
8. Crossing designer interface shows plants that are selected
9. Crossing designer interface contains opportunity to select plant 1 and plant 2 separately
10. Crossing designer interface shows the goal's properties, during selection
11. Crossing designer interface contains opportunity to save selected material
12. Crossing designer interface shows property values of the plant material
13. Crossing designer interface shows material that has been tagged as interesting during selection.

Compare plant material

1. User can compare at least 4 plants in one screen
2. Crossing designer shows property values of the plant material
3. Crossing designer interface shows the property values of different plants next to each other.
4. Crossing designer shows the goal's property values.
5. Crossing designer interface shows the properties of plant material which have a different value than the goal
6. User can change the order of plant material that is displayed
7. Crossing designer interface should contain the opportunity to make a cross when two plants are compared
8. User should be able to set which properties the interface will show.

Crossing scheme

1. Crossing designer user interface should show the possible crosses
2. Crossing designer interface should have the opportunity to add extra crosses
3. User should be able to select material to be crossed
4. Crossing designer interface shows whether a cross has been made before
5. User is able to add notes to crosses
6. User is able to select crosses
7. Crossing designer interface should give the opportunity to compare the plants of a cross.
8. Crossing designer interface shows plants that are selected
9. Crossing designer interface shows crosses that have been tagged as interesting during selection
10. Crossing designer interface contains the opportunity to save selected crosses.
11. Crossing designer has the opportunity to order crosses.
12. User is able to selected crosses individual
13. User can select at lest 20 crosses together

Ideas

The requirements for the crossing designer are defined for the different functions of the crossing designer. The principles of a morphological scheme[1] are used for idea generation, by splitting up the functions in different parts. For the different parts of the functions there is thought about solutions[2]. Combining different solutions of the parts with each other will create different concept direction for the crossing designer. The morphological scheme is used, because the crossing designer has multiple functions that all have different solutions. Therefore it is hard to come up with single ideas of how the crossing designer should look like.
For the idea generation there is focussed on the functioning of the crossing designer and not on the design of the interface. The ideas are described and supported with basic sketches.

2. *Morphological scheme* splits out a multi-complex problem into smaller problems were solutions are made for. These solutions can be combined with each other to generate solutions for the multi-complex problem.

1. Ritchey, 1998

Set a Goal

Create new goal or choose an existing goal

To work with a goal the breeder should be able to create a goal or to select a goal to work further with. Different ways of how a breeder can start working with a goal are created.

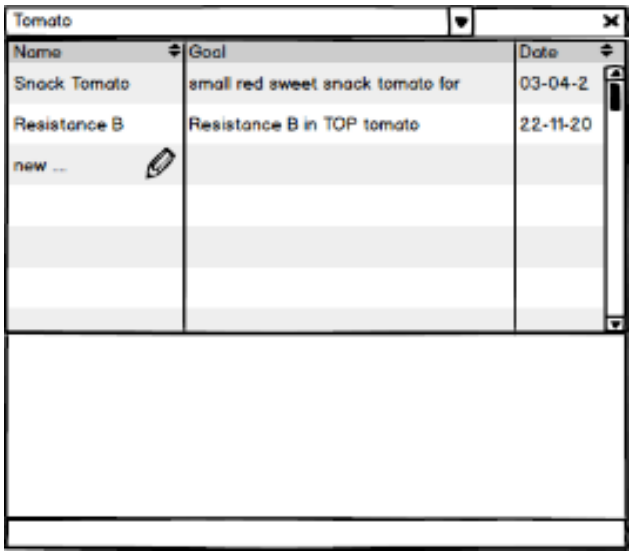


Figure 9.1. Goals are linked to the crop where the breeding is done for.

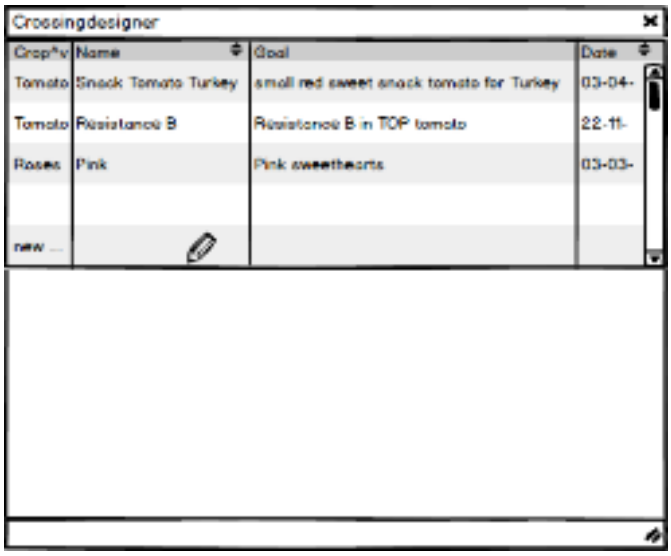


Figure 9.2. All the goals in the database are displayed and can be selected by the breeder.

Goals can be part of a crop, whereby the breeder first selects the crop that is breed for. After selecting a crop, the existing goals for this crop will be shown and can be selected, or there is the opportunity to create a new goal *(Figure 9.1)*.

All the goals in the database of the crossing designer can be showed in a list, displaying at least the crop were is breed for and the name of the goal. To find a goal to work further with the goals can be ordered on the displayed properties. Goals can be selected to work further with, but there is also the opportunity to create a new goal *(Figure 9.2)*.

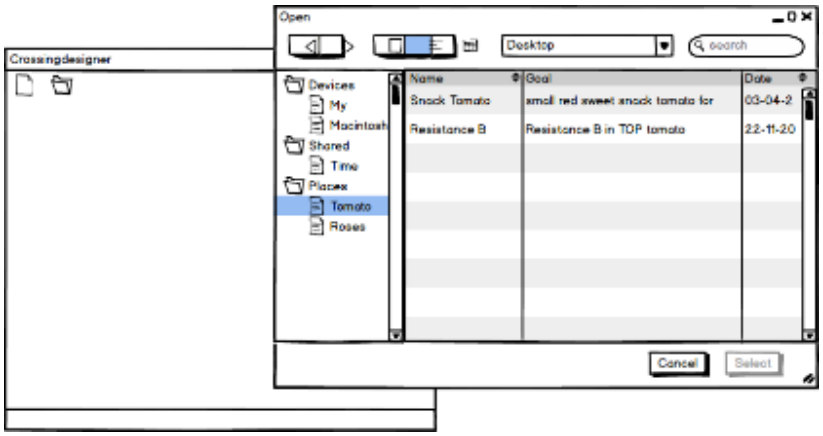


Figure 9.3. The breeder has the option to create a new goal or open an existing goal.

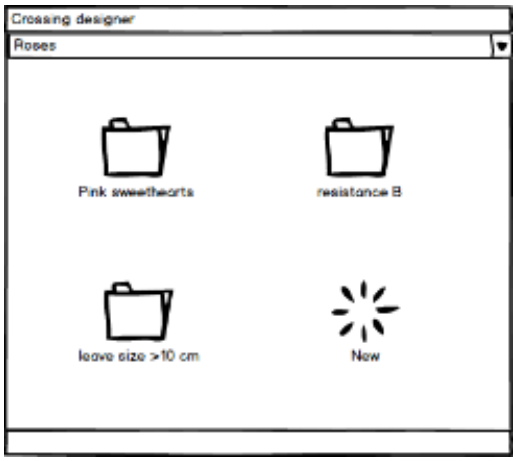


Figure 9.4. Goals and the creation of a new goal are displayed by the use of pictograms.

The breeder has to choose between opening an existing goal or create a new goal. When the breeder chooses to open an existing goal a pop-up, with a list of all existing goals to choose from, will disappear *(Figure 9.3)*.

The existing goals are displayed with pictograms as well as the option to create a new goal. The name of the existing goals is displayed underneath the pictograms *(Figure 9.4)*.

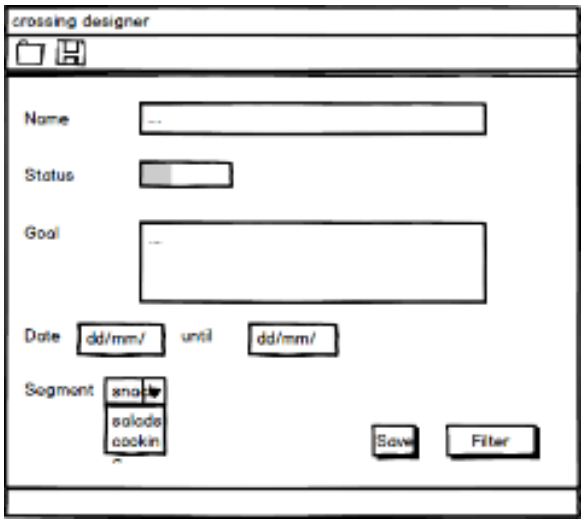


Figure 9.5. A new goal form is opened or the breeder has to open an existing goal.

A blank document to create a goal is displayed, which can be used by the breeder immediately to create a new goal. When the breeder wants to work further with an existing goal he can choose the button to open an existing goal *(Figure 9.5)*.

Set a goal

When a new goal is created, the breeder first has to set some information about the goal. Different ways of how the breeder could set the information about the goal are created.

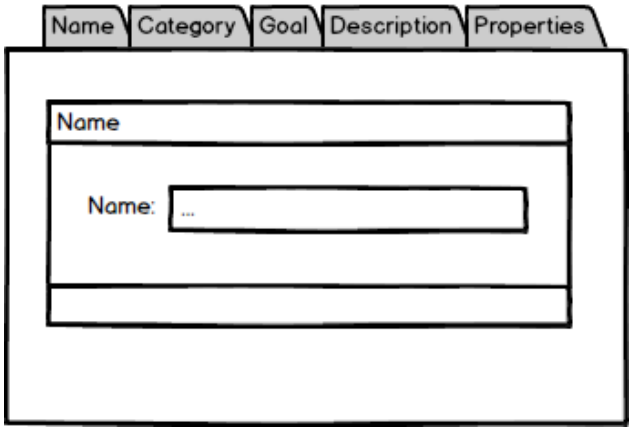


Figure 10.1. The system will show step by step which information the breeder has to give in order to set the goal.

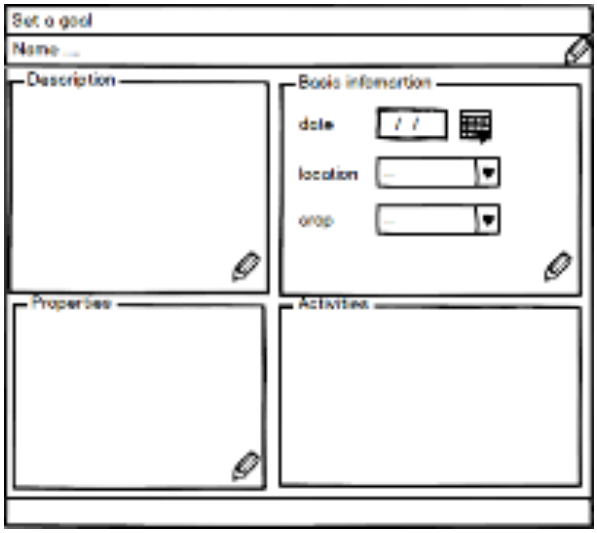


Figure 10.2. The breeder can decide which information to e the system to set a goal.

The system will guide the breeder in setting the goal. The system will show step by step which information the breeder has to give in order to set a goal. After finishing all steps the system will create the goal *(figure 10.1)*.

The breeder can set a goal and determine which information should be given. The breeder will get an empty form of a goal and can decide which information to fill in *(figure 10.2)*.

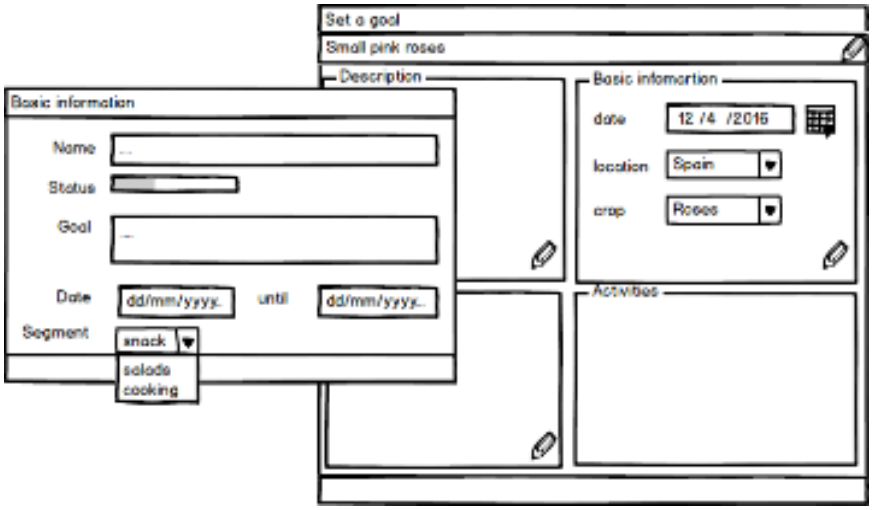


Figure 10.3. The breeder first has to set the basic information and can optionally add more information to the goal.

To set a goal the breeder first has to give some basic information in a pop-up form that the system will show. This information will be placed in an empty form of a goal by the system. The breeder can decide or more information should be added to the goal by completing empty information *(figure 10.3)*.

Activities

To achieve a goal a breeder has to make different crosses over multiple generations of plants. All these crosses are activities to achieve the goal. Different ways of how these activities should fit in the goal that is created by the breeder in the previous steps are created.

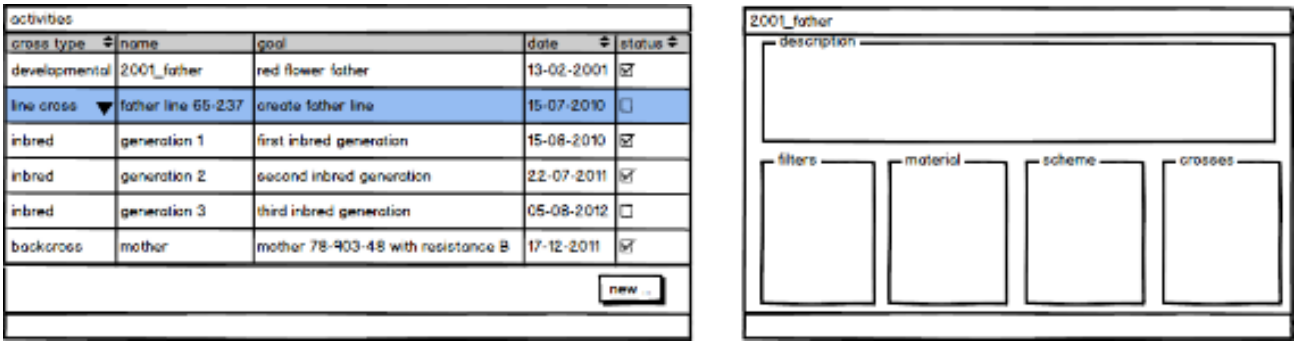


Figure 11.1. Activities are placed in a list and can be opened. In the activity the needed filters, material lists and crossing schemes can be find.

All activities are displayed in a list with information such as the goal it belongs to and the name. From the list the breeder can select an activity or create a new activity. The activities represent the different types of crosses and are linked to the goal where the crosses are done for. When an activity is selected the activity form will open. Within this form the breeder can make or work further with filters, material lists and crossing schemes for that activity. The breeder can set the status of the activity, to know where is worked on (*figure 11.1*).

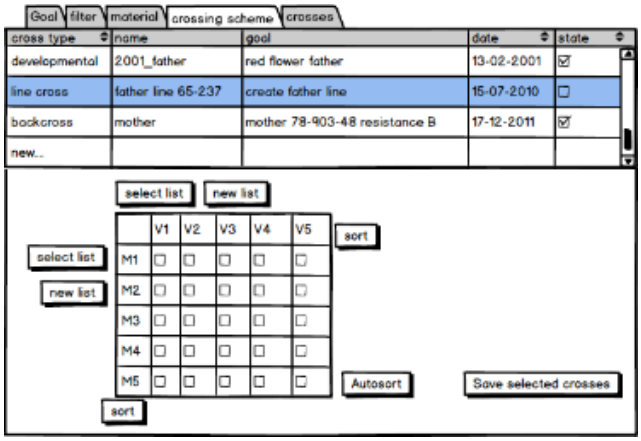


Figure 11.2. Activities are integrated with the goals.

Activities are integrated in the goals. The material lists, crossing schemes and filters are not grouped under an activity but are part of the goal. The breeders can integrate data from different activities with each other to a new activity. For example when the breeder wants to create a new material list it could already make use of an existing filter that is also used for another material list (*figure 11.2*).

Set properties

Select properties

When the breeder sets a goal, the goal will be defined with properties. Therefore the breeder has to select the properties that are applicable on the goal. Not only during the setting of the goal the breeder has to select properties, but also when the breeder creates a filter. Consistency is one of the design principles that are applicable on the design of the crossing designer. Therefore it is better to have the selection of properties the same everywhere in the crossing designer. Different ways of how the breeder could select properties are created.

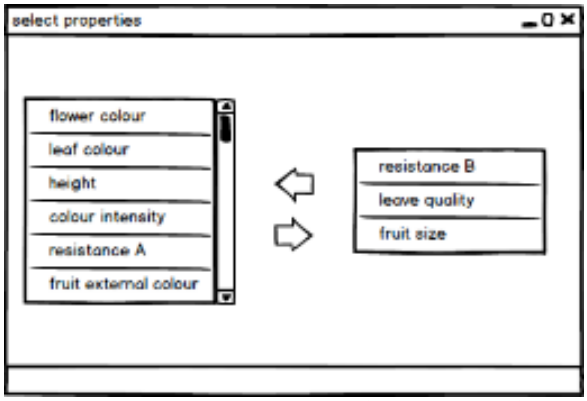


Figure 12.1. The breeder selects from the list of possible properties which to use.

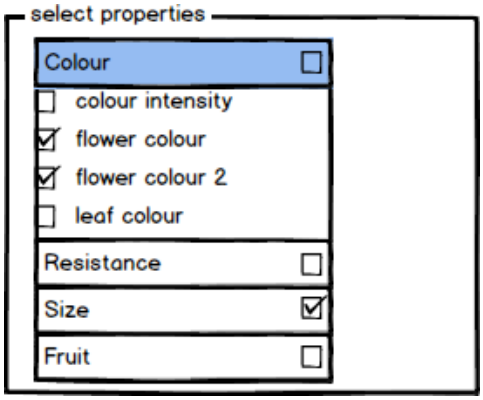


Figure 12.2. The breeder can select single properties or property sets.

All the possible properties are displayed in a list. The breeder can select properties by placing them in the property list *(figure 12.1)*. Both lists are displayed to make sure that the breeder knows what is already selected and which possibilities are left.

Properties are divided over property sets[1]. The property sets are displayed and can be enrolled to show which properties the set contains. The breeder can select all properties in a property group by selecting the property group, or can select properties individually from each other by selecting a single property *(figure 12.2)*.

1. *Property set* is a group of properties that is related to each other.

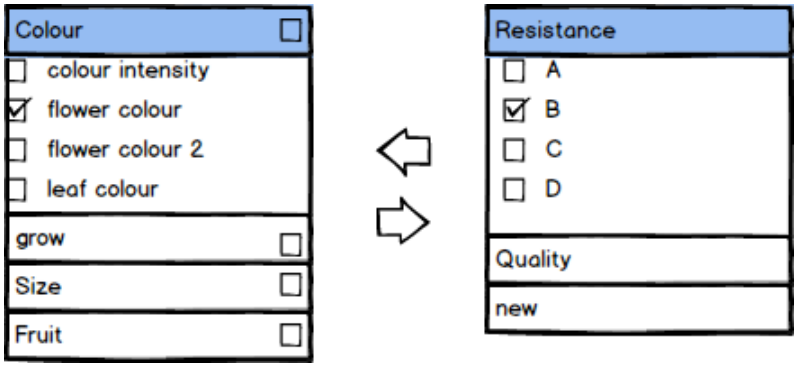


Figure 12.3. The breeder select from a list of properties and property sets, which to use. The breeder also can create new property sets.

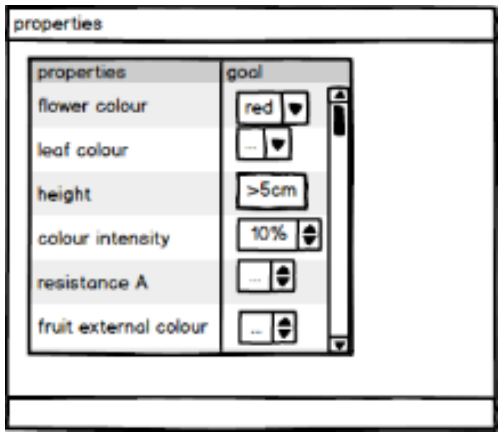


Figure 12.4. Properties are selected by giving them a property value.

All the possible properties and property sets are displayed in a list. The breeder can select single properties and property sets by placing them in the property list. The breeder also can make a new property set in the property list, by creating a property set and place properties in this set *(figure 12.3)*.

All possible properties are placed in a list and the breeder can enter a value for the properties. Properties are selected by giving a value for the property. When the property should not be taken into account, no value needs to be set for that property *(figure 12.4)*.

Set importance value for a property

The crossing designer should give users the possibility to set an importance value for a property. Different ways of giving properties an importance value are created.

Property values can be given to properties by giving each property an individual score of importance *(figure 13.1)*. There are different scoring methods to define the importance value;

- A percentage (%) of importance is given, the higher the score the more important it is.
- Rank the properties by ordering them from on importance.
- Make groups of importance of the properties (high, medium or low) *(figure 13.2)*.
- Give properties a mark, by first defining the scale of the marks.

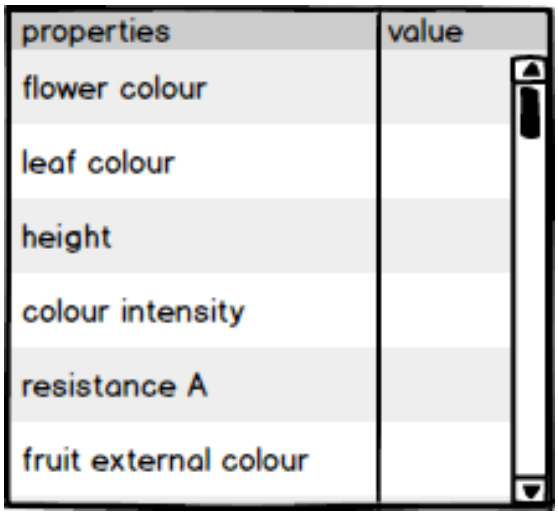


Figure 13.1. Properties are scored individually with an importance value.

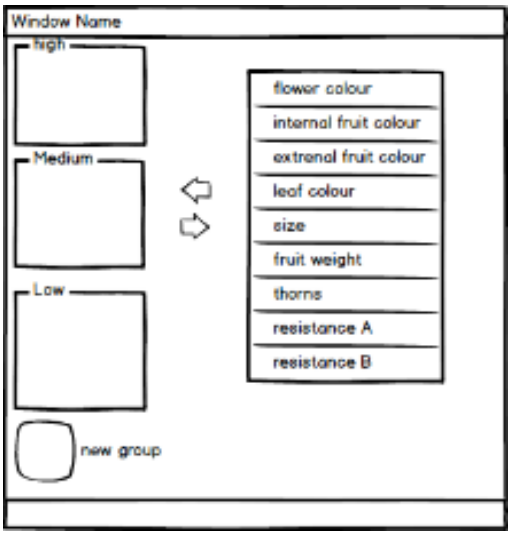


Figure 13.2. Properties with the same importance value are grouped together.

Create Filter

Set Filter

To find potential plant material in the database, the breeder will use a filter to go through the database. The filter will search for plant material with specific values for properties. The breeder filter is set when the breeder defines the values for the properties. The value for the properties depends on the goal's properties that are set. Different ways of how the breeder could make use of a filter to go through the database to search for potential plant material are created.

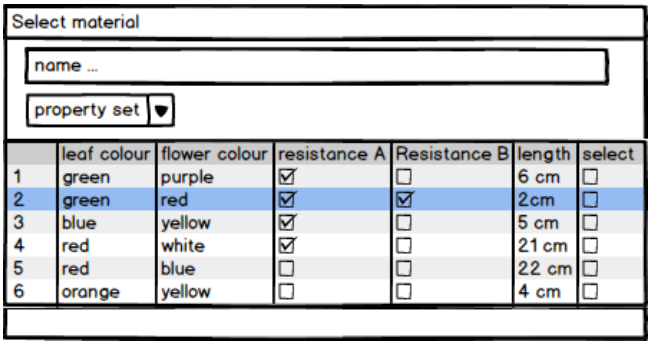


Figure 14.1. The system creates a filter from the setting of the goal and shows the potential plant material

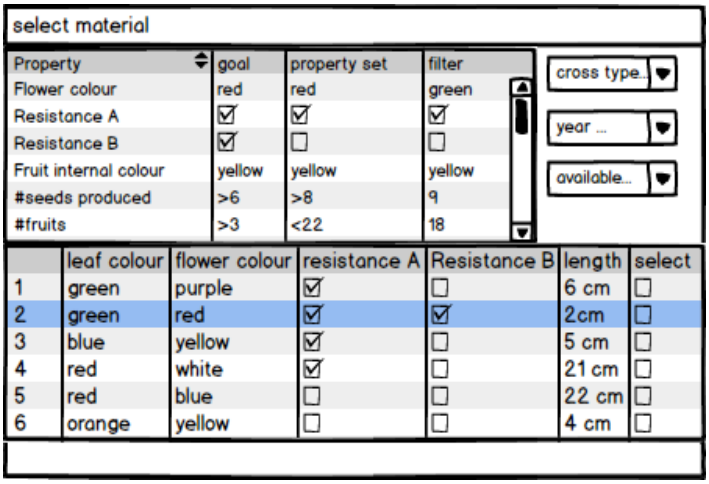


Figure 14.2. The breeder can adapt the filter settings to the filter results.

The system creates a filter from the goal's properties and corresponding values. The filter that is created is used to search through the database *(figure 14.1)*. For this idea it is important that the goal is defined specific to make sure that the system can generate a useful filter. The result is a list of all potential plant material, wherein the breeder can select.

The setting of the filter and the selection of plant material are displayed together. The filter settings are placed displayed next to the goal and the property set. The filter will automatically get the values of the property set, but can be manually changed. The breeder might change the filter setting to get more or less results. That's why the results are displayed together with the filter setting *(figure 14.2)*.

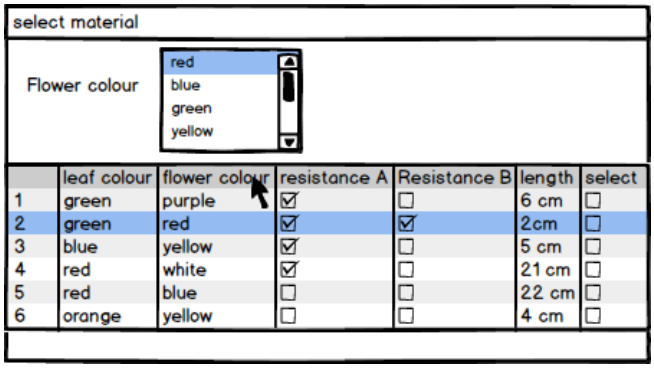


Figure 14.3. For each property a filter can be made. The breeder is able to see the effect of a filter setting on the group of potential plant material.

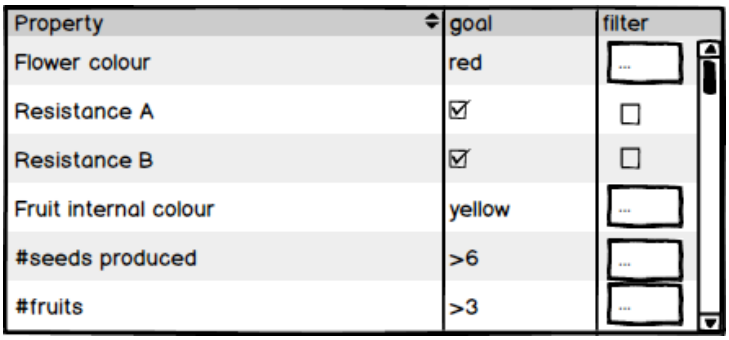


Figure 14.4. The breeder will set the filter by giving the properties to filter for a filter value.

All the plant material from the database is displayed with the corresponding properties and values. For each property the breeder can set a filter. When the breeder clicks on the property the filter setting of that property will be visible and the breeder is able to change the properties. When a filter setting is done, the list will be filtered and up-dated *(figure 14.3)*.

The properties that are set in the goal are displayed as a list with their values. The breeder will set a filter by giving a filter value to the properties that should be included in the filter. The filter can be saved and used to find potential plant material *(figure 14.4)*.

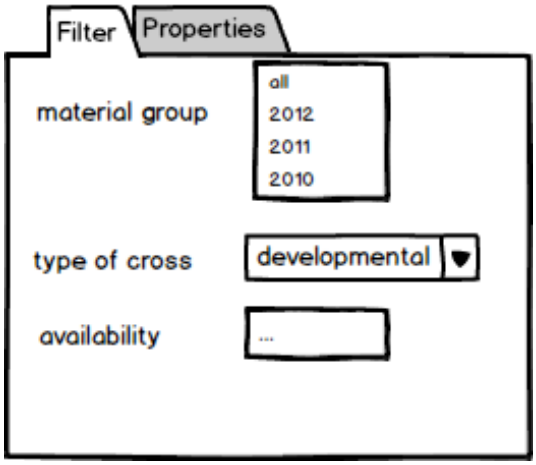


Figure 14.5. The basic information and the property values are set separately from each other during the setting of the filter.

There can be filtered for two kinds of information, the basic information and the property values of the plant material. The filter setting can be made in the same way as in E-Brida whereby the two types of information are set separately from each other for the filter. When the breeder set the filter there are two tabs, in the first tab the basic information filter options can be set and in the second tab the property values filter options can be set *(figure 14.5)*.

Select Material

Select plant material

From the offspring of the crosses the breeder selects the plant material to work further with. Different ways of how the breeder could select plant material are created.

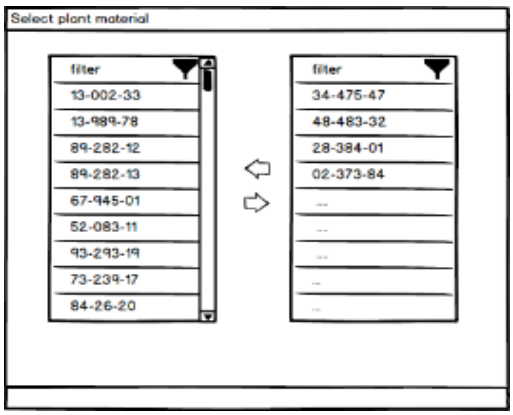


Figure 15.1. The selection of plant material in E-Brida.

	leaf colour	flower colour	resistance A	Resistance B	length	select
1	green	purple	☑	☐	6 cm	☐
2	green	red	☑	☑	2cm	☐
3	blue	yellow	☑	☐	5 cm	☐
4	red	white	☑	☐	21 cm	☐
5	red	blue	☐	☐	22 cm	☐
6	orange	yellow	☐	☐	4 cm	☐

Figure 15.2. Material is selected by ticking a check box

The selection of plant material can be the same as in E-Brida. The plant material is displayed as a list at the left and plants that the breeder wants to select can be placed with arrow buttons to the material list displayed at the right *(figure 15.1)*. Within the material list the breeder can filter to find potential plant material.

All plant material has a checkbox that can be ticked when the breeder wants to select the plant material. The selection can take place during the filtering of the plant material. Each plant can be selected individually. The breeder can select all plants by ticking the checkbox of select *(figure 15.2)*.

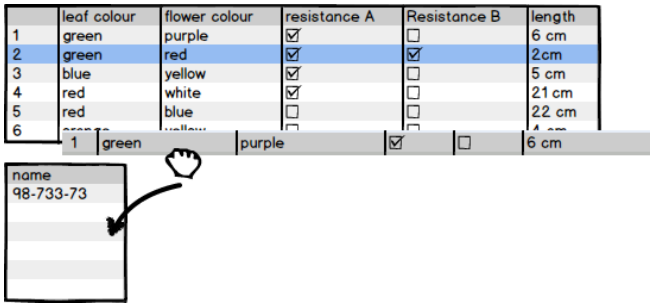


Figure 15.3. Material is selected by dragging it into the material list.

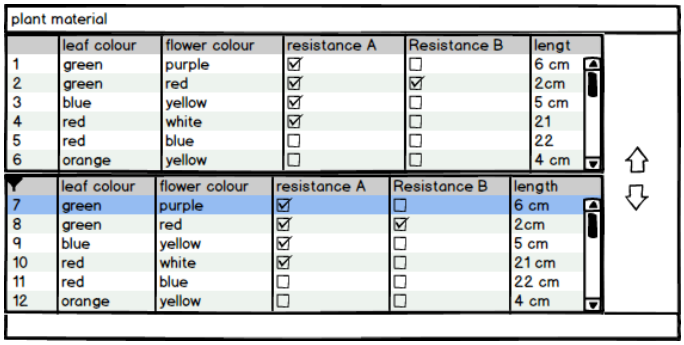


Figure 15.4. Material can directly be selected from the filter results.

The plant material that the breeder wants to select can be dragged from the filter result in a material list. Plant material can be deleted from the material list by dragging it out the list, and the system will automatically place it back at the filter results *(figure 15.3)*.

The material list is displayed under the filter results and both are displayed as a list of plant material with the corresponding property values. The breeder can select material from the results and place it in material list. The breeder will have an overview of all the properties of the filtered plants and selected plants *(figure 15.4)*.

Compare plant material

Comparison of plant material

A breeder can compare two plants with each other when it might be a potential cross. The breeder will compare the property values of the plants with each other to predict if it will give the promising offspring. The breeder will look at the combination of the property values of the plant in comparison to the goal. The breeder could also compare plant material to decide which plant would be a better parent. In that case the breeder will look which plant has better property values to combine with the other parental plant. Different ways of how the breeder could compare plant material with each other are created.

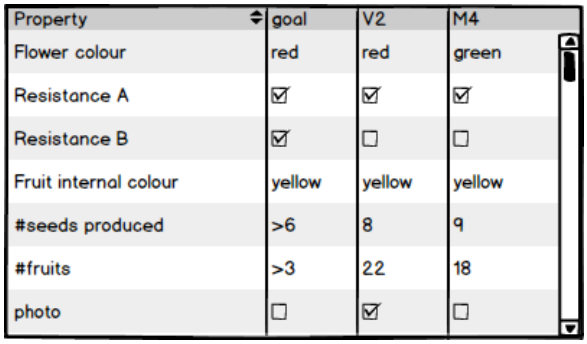


Figure 16.1. Plant material is placed horizontally and compared to the goal.

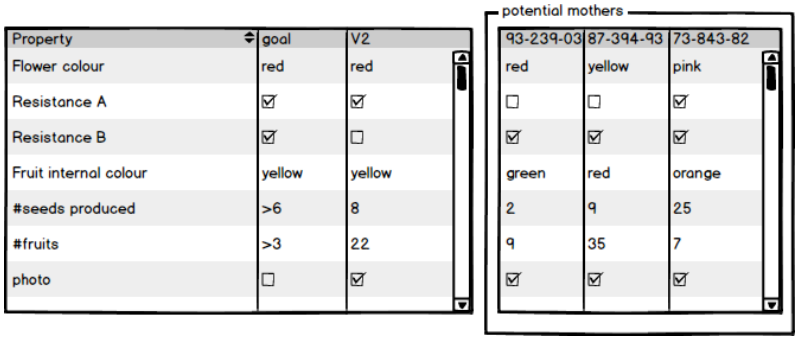


Figure 16.2. Plant material of potential matching plants is compared to the goal and selected parental plant.

Plant material is placed horizontally next to each other, with underneath the values for the properties. The goal is also shown as a plant so that the breeder can compare the plants with the goal. The breeder can change the order of the plants. When a breeder wants to compare two plants they can be placed next to each other, which makes it easier to compare the property values *(figure 16.1)*.

The breeder can compare potential parental plants for a selected parental plant. The selected plant and goal is showed, in a separate box the potential matches are showed and can be compared to each other, but also with the goal and the other parental plant *(figure 16.2)*.

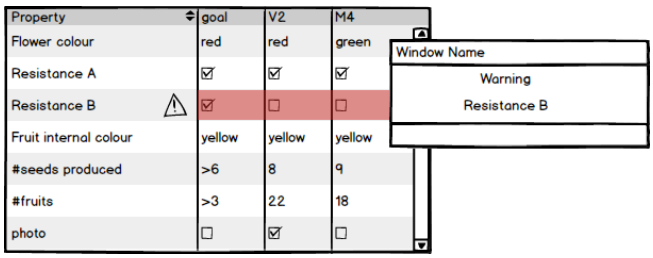


Figure 16.3. System will warn the breeder when plant material combinations will not achieve the goal.

	leaf colour	flower colour	resistance A	Resistance B	length
1	green	purple	☑	☐	6 cm
2	green	red	☑	☑	2cm
3	blue	yellow	☑	☐	5 cm
4	red	white	☑	☐	21 cm
5	red	blue	☐	☐	22 cm
6	orange	yellow	☐	☐	4 cm

Figure 16.4. Plant material is placed in a vertical list with properties and can be compared with each other.

Plants material is compared as a match and to the goal. The system will give a warning when the combination of properties will not give the result of the goal *(figure 16.3)*. The system makes the comparison, but the breeder has to decide what to do with the information. It makes sure that the breeder won't miss information, what can happen when a lot of data are showed. There are different ways to warn the breeder:

- Colour
- Sound
- Pop-up screen
- Illustration

The plant material is placed under each other in a list with the properties. The breeder can change the order of the material and can compare the properties. Multiple plants can be compared at the same time *(figure 16.4)*.

Crossing Scheme

Information about crosses

The crossing scheme shows all the possible crosses from the material selection in the previous steps. The breeder has to decide which crosses should be made. The breeder needs some information, to decide whether to make a cross or not. Different ways of how the crossing scheme should show the information about the cross the breeder needs to decide if a cross should be made are created.

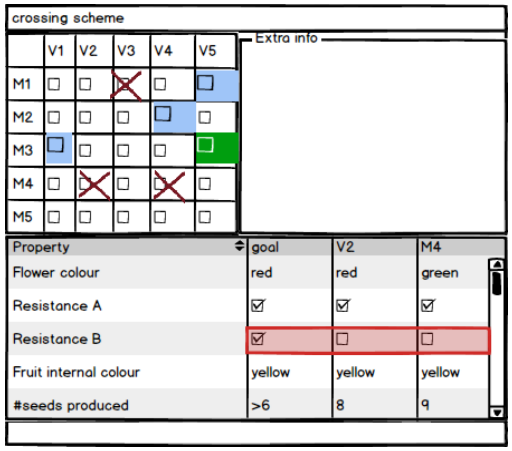


Figure 17.1. All the information to select crosses is visible in the screen.

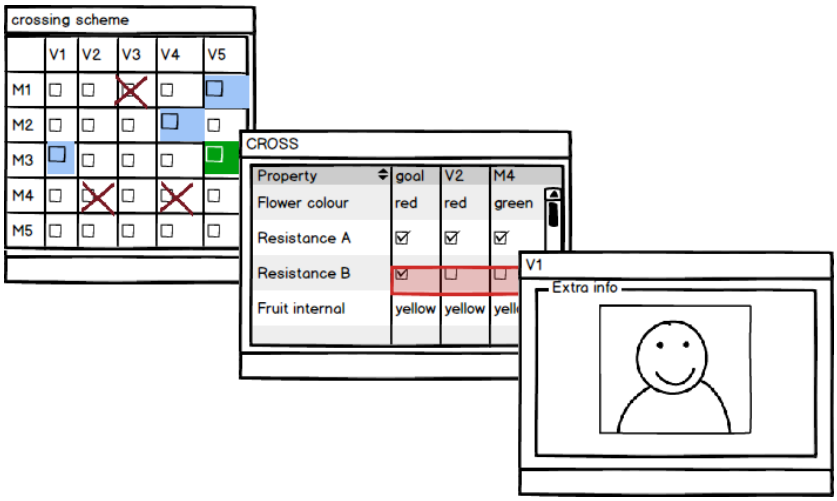
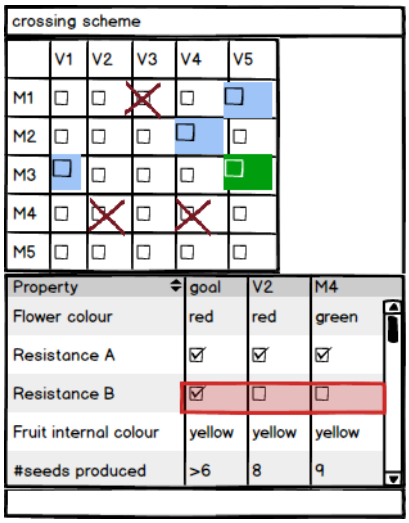


Figure 17.2. A pop-up screen will give more detailed information about a cross or plant.

1. Page 19

The crossing scheme and the information are displayed in the same screen. In the scheme the most important information[1] is given with colours. The breeder can select a cross to get extra information about it and to compare the properties of the parental plants with each other *(figure 17.1)*.

The crossing scheme is displayed, and by clicking on a cross there will be a pop-up screen with information about the cross. By clicking on the plant material a pop-up screen will give information about the properties of the plant *(figure 17.2)*.



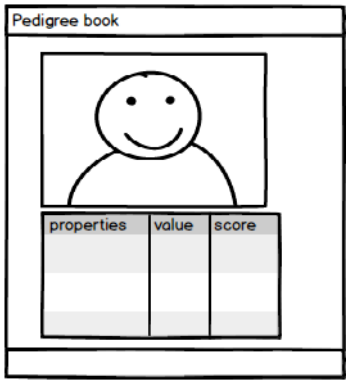


Figure 17.3. To get information about the plant material the user is linked to the pedigree book of E-Brida.

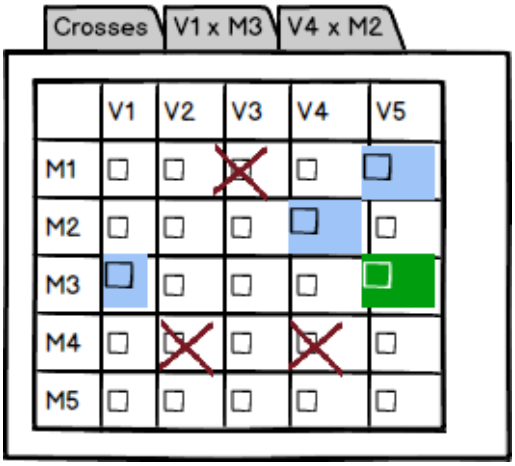


Figure 17.4. When a cross is selected a new tab will open with information about the cross.

The crossing scheme is linked to the pedigree book of E-Brida. Crosses are showed and information about the cross will be showed when the cross is selected. To have information about the plant material, the breeder can select the plant and is send to the pedigree book of E-Brida *(figure 17.3)*.

The crossing scheme is displayed on the first tab, when the breeder selects a cross and wants to have information and a new tab will be opened. There can be switch between tabs and tabs can be quit. By switching between the tabs the breeder can compare crosses with each other *(figure 17.4)*.

Conclusion

For the different functions of the crossing designer, there is thought about different ideas how these functions could work or look like. The different ideas have been combined resulting into three concept directions.

Step by step structure, this idea is focused on making the crossing designer a support tool through the whole process of the making of crosses. The focus is on making a simple system that is easy to use. The crossing designer will be the leader of the process and the breeder only have to give his knowledge as input to the system and to make decisions. The software will guide the breeder through the breeding process.

E-brida, this idea is focused on making a crossing designer that is part of the E-Brida software. The crossing designer has to be integrated with the other functions of E-Brida. In this concept the working of the functions of the crossing designer are based on the current functioning of E-Brida.

Web-based, this idea is focussed on making a web-based application. The crossing designer will be a platform wherein breeders can work together on breeding projects. It will have different functions to support the process of making crosses.

Concepts

During the idea phase different ways of working for the different functions are created. The ideas have been combined and together with the results of the analyses there are three concept areas defined; Step by step structure, Web-based and E-Brida. The functions and the structure are the same in the concepts, which were defined during the analyses[1]. The concepts differ mostly in their usage and on the presentation of information. The concepts will be described by their layout and the order of usage when a breeder wants to make a cross.

1. Page 12

Concept 1 – Step by step structure

This concept has a usage structure whereby the crossing designer will guide the breeder through the steps of making a cross. In this concept the division of all steps are showed with numbers, and should give the user the idea where in the process he is. In this concept all steps are divided into sub steps, so everything only can be done in that order. In the screen the breeder knows exactly where he is. The screen *(figure 20)* is divided in 3 areas. In the top there is the main menu and information about the user. The breeder can switch between the main steps, and knows which main step is opened. At the left side of the screen there is the submenu, all the different steps of the main step are displayed there. The steps are presented with numbers, ordered in how the steps should be taken. The step that is open will be highlighted, so the breeder knows where he is. The breeder has to walk through all sub-steps to finish a main step. The third area is the working screen, where all the steps take place. This field is most dynamic because it changes for every step. Every step has a different function and the user has to give different input in each step. In the work screen is an extra area which can be seen as the forth area which is also a menu. For a lot of sub steps different input has to be given. To make sure everything will be given this is also split out in smaller steps, so that the system guides the breeder through the breeding process.

Log In

The user first has to log in, to use the crossing designer (*figure 18)*. Besides log in codes the choice of crop is important, to makes sure that the crossing designer picks the right database to work with. At some companies crops are defined even more specific in segments, and then the breeder also has to select the segment to work with. The breeder can always log out or change the crop while using the crossing designer, by clicking on the log in information in the top menu.

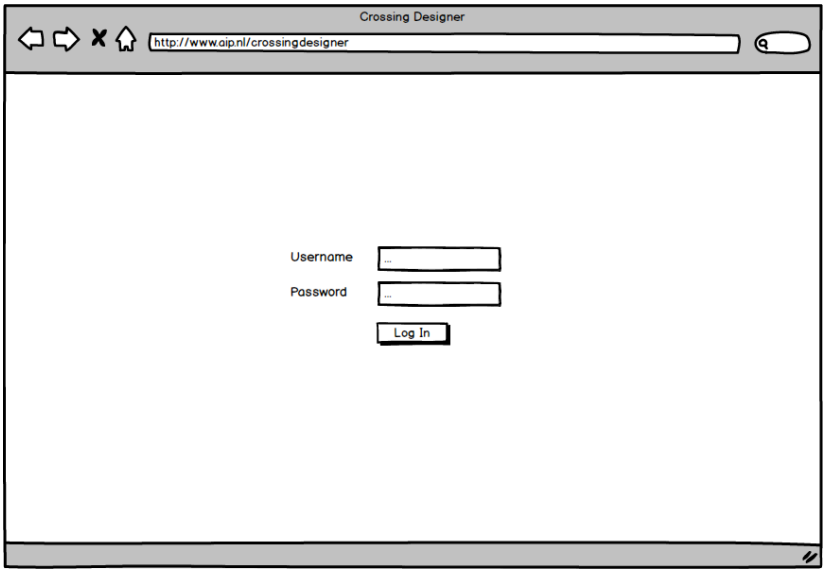


Figure 18. Screen shot of the Log In screen of the step by step structure concept.

Goal

After logging in the user will set the breeding goal or work further with an existing breeding goal. To make a new breeding goal the breeder has to follow the steps of the system that support the defining of the goal. Every information insertion for the goal by the breeder is a new step in the process. When all steps are done the breeder will get an overview of the goal that is set with the steps. When the breeder works further with an existing goal the description overview of the breeding goal will be displayed. The user will skip the steps of setting the goal. When the breeder wants to make changes to the goal all the steps to set the goal has to be walked through in order to change something. The breeder first will set the basic information[1] of the goal, which is the making of the goal (*figure 19*).

1. Page 13

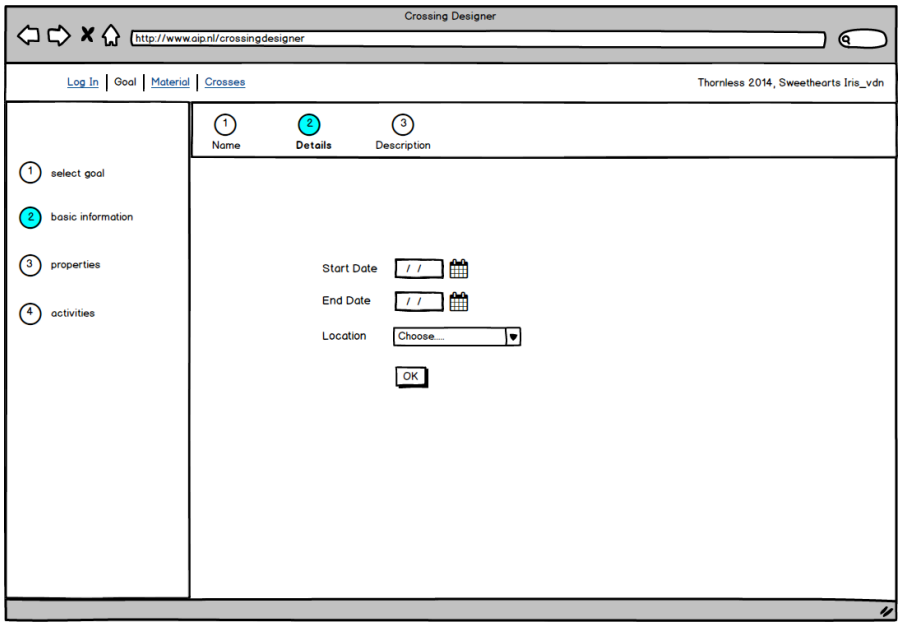


Figure 19. Screen shot of setting the detailed information of a goal in the step by step structure concept.

After defining the basic information of a goal, the properties of a goal need to be set. The breeder first has to select the properties and then give the properties a value and importance value. The breeder can select single properties or select a whole property set (*figure 20*). The breeder first selects properties and sets by ticking the checkbox and with the arrows they will be placed in the list of selected properties. The breeder also can create new property sets while selecting the properties. The breeder will click on create new property set and at the right the name and function of the new property set can be filled in. After setting the new property set, the property set will be placed in the selected box of properties, and the breeder can place existing properties in the property set. The set will be saved and can be used later on as well.

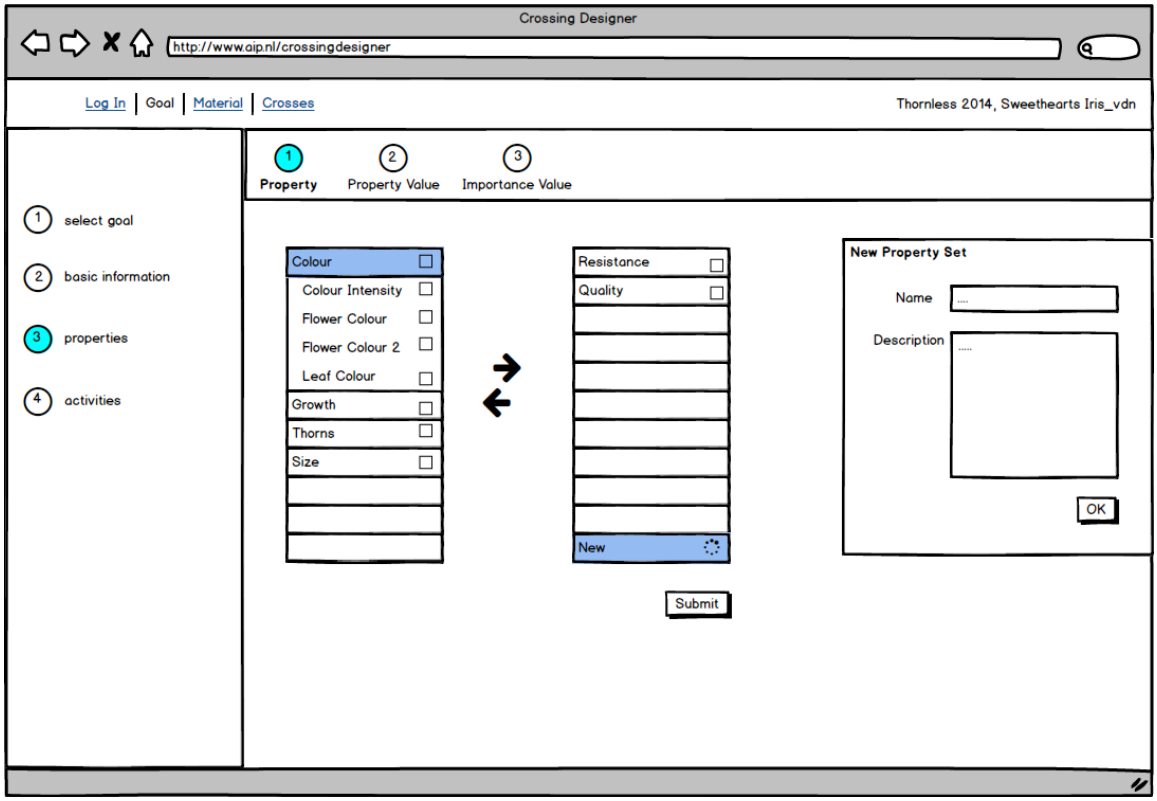


Figure 20. Screen shot of selecting properties in the step by step structure concept.

After selecting the properties the property value is set in the next step and the third step the importance value of the property is set. The setting of property value and importance value is almost similar. In both cases the breeder selects the field to fill in the value. At the right side there will be a box wherein the breeder can select from the available values for that property.

After setting the goal the breeder can make an activities to achieve the goal. The activity will be the input for the next step. When a breeder creates an activity, he will set the information[1] that is needed to create one. The setting of the information will be similar to setting the information of the goal.

1. Page 15

Material

After selecting an activity the next main step is to select the plant material, which the user want to use for the crosses. To find suitable plant material to have promising crosses, the breeder first has to set a filter. The users can use an existing filter to find plant material or create a new filter. When the breeder selects an existing filter the breeder gets an overview of the filter settings and is able to change these settings. When the breeder changes the settings, all steps of setting a filter has to be walked through. The filter will be set and the breeder can makes changes where needed, and save the filter as a new filter or replace the existing filter. When the breeder creates a new filter the breeder has to set a name. The filter becomes part of the activity, when the breeder wants to use the filter in a different activity he has to import the filter. To create a new filter the breeder first has to set a name for the filter. When the name is set there can be filtered on two types of information. First the filter for basic information[1] is set and then the filter on the properties. The properties that have been set for the goal and belonging values of the properties are displayed. The filter values for the properties are already filled in with the goal's property values. The breeder can change the filter values for each property. The breeder also can give properties inheritance rules[2] so that the breeder can filter more specific on combinations of plants. To finish the filter the breeder has to set the importance value for each property in the filter. The breeder can give it a value between 5 (low) to 1 (high). The importance value will help in ordering the filter results for the most promising plants.

1. Page 16
2. Page 17

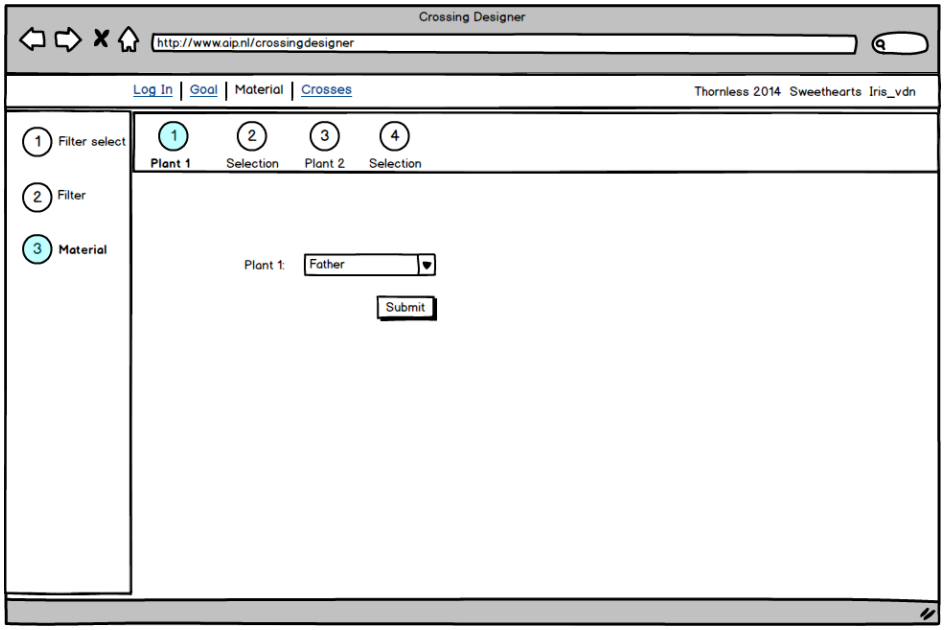


Figure 21. Screen shot of selecting the plant type for selecting material in the step by step structure concept.

After setting the filter the breeder can use the filter to find promising plant material. The breeder is able to filter separately for father and mother plants (*figure 21*). When the breeder filters for plant 1, the breeder can define or plant 1 is a mother or father plant or that there is no difference made. After selecting the plant to filter for the breeder has to select the filter that will be used. The system will apply the filter on the database and will display the results. The results are a list of plant material, which properties correspond the filter settings ordered by the importance values. The properties of the plant material are showed and the breeder can select plant material, which he would like to use to cross with. The breeder might want to change from filter, because of the results. The breeder has to go one step back to change filter. If the breeder wants to change the settings of the filter the breeder goes back to the step of the filter settings. The breeder then can change the filter settings, but he has to walk through all steps before he can filter the plant material again. The plant material the breeder selects from the results will form a new list of plant material that can be saved and used later on to make crosses. The breeder will give the list a name and it will be saved.

When father and mother plants are selected separately the step of filtering and selecting the plant material will be done twice. The systems knows from how plant material 1 is defined or there will be filtered for plant material 2 as well. The two material lists will be saved separately from each other but will be linked to the same goal and activity.

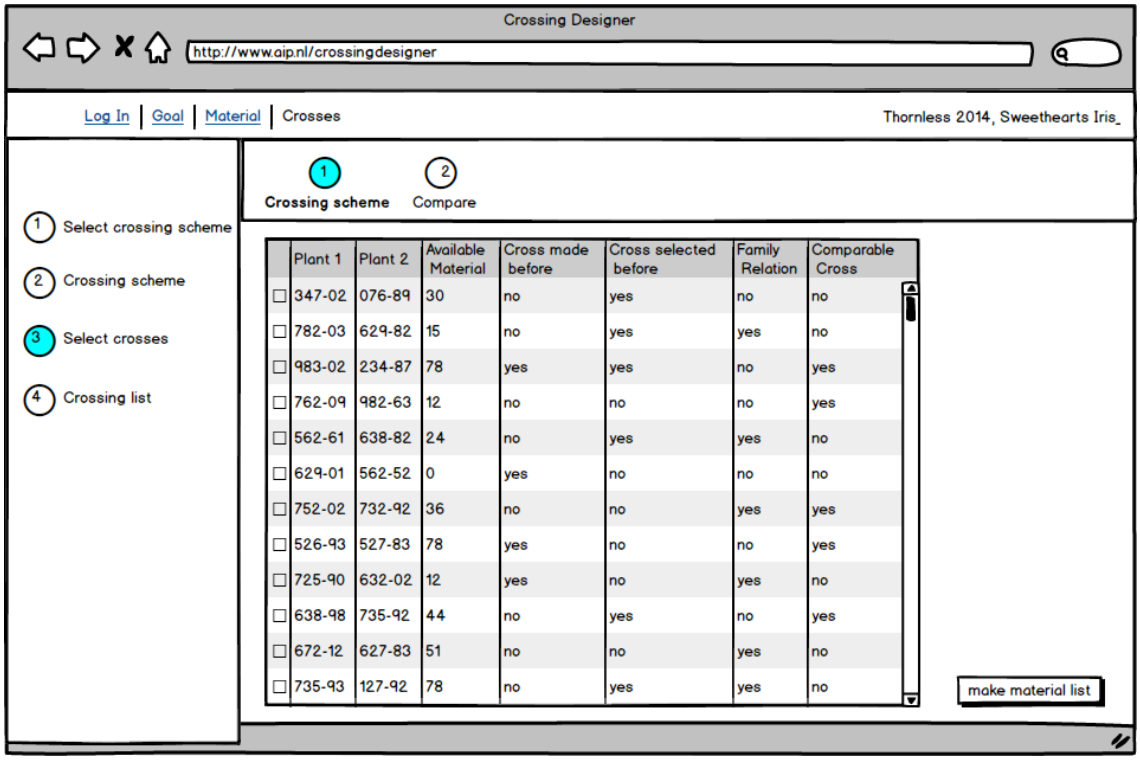


Figure 22. Screen shot of the crossing scheme in the step by step structure concept.

Crosses

The breeder has made lists of promising plant material to cross with each other. There are lists that have to be combined, because father en mother plant material is selected separate from each other and there are lists where the selected plants can cross with each other. The breeder has to select from all possible crosses the most promising ones. The breeder first has to make a new crossing scheme or work further with an existing crossing scheme. The crossing schemes are also part of the activity. When the breeder works further with an existing crossing scheme, the crossing scheme will be displayed and he can immediately select crosses. When the breeder wants to make changes to the crossing scheme he has to walk through the same steps as creating a new crossing scheme, but then information is already filled in and he only has to make a change. When the breeder creates a new crossing scheme, first a name for the crossing scheme has to be set. When the name is set the breeder selects the plant material lists. The breeder will select two lists, the plant 1 list and plant 2 list. When there is no difference between plant material 1 and plant material 2 the breeder will select the same material list for both. The breeder is also able to use multiple lists for plant material 1 or 2 when he would like to combine lists. When the material is chosen the crossing designer will make all possible crosses with the material. A list with all possible crosses will be showed (*figure 22*).

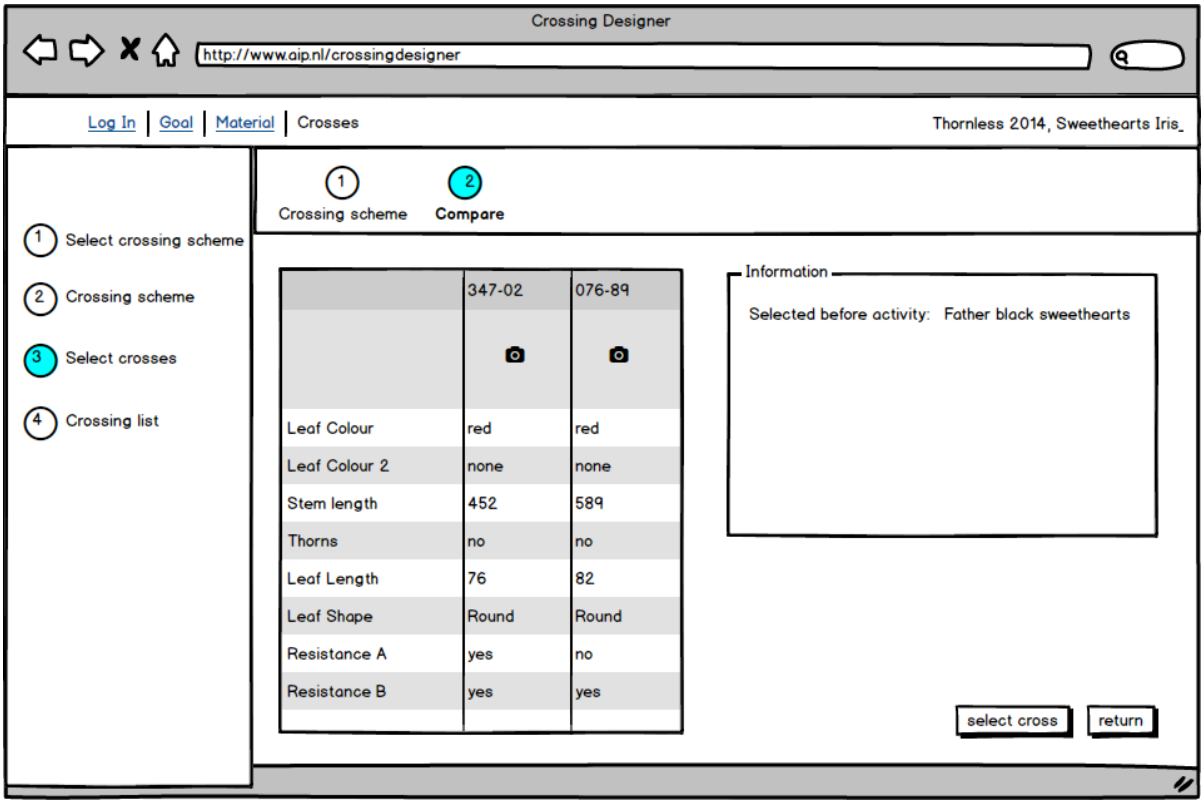


Figure 23. Screen shot of comparing plant material of a cross in the step by step structure concept.

1. Page 19

In the list the important information[1] about the cross such as if the cross is made before is shown. The breeder can select a cross with the check box of the cross in the list if he wants to make the cross. The breeder also can compare the plant material of a cross by selecting the cross. The breeder will select the cross and go to the next step. The software will place the two plants and their properties and corresponding values next to each other, so that the breeder can judge if it will give promising offspring. It will also show the details of the important information such as when a cross is made before. The information and the comparison will give the breeder more insights about the cross and the breeder can determine better whether cross should be made or not (*figure 23*).

When the breeder has selected all the crosses that should be made, the next step is to make a crossing list. The crossing list will be made by the system and it will place all selected crosses in a list underneath each other. A selected cross is displayed as plant 1 x plant 2, and the expected pedigree number of the offspring. This list is the final overview for the breeder of the crosses that will be made. To confirm the crosses the breeder has to select the crosses, he can select them all at once. The selection gives the breeder the opportunity to make changes. The selected crosses will be saved as a list that can be used in the next step, which is the pollination plan of E-Brida.

Concept 2 – E-Brida

This concept is based on the existing breeding software E-Brida developed by AIP. The crossing designer will support the breeder in the breeding process in the steps before E-Brida starts supporting the breeder. The output of the crossing designer is the input for E-Brida. Therefore AIP already mentioned that they want the crossing designer to be part of E-Brida. This concept has the same structure as E-Brida. The crossing designer will be a function just like the pedigree book in E-Brida. The crossing designer has three sub-functions (goal, material and crosses) that will help the breeder in making promising crosses. The sub-functions can be used separately from each other. The breeder can use the functions, which apply to his personal working way. The steps that need to be taken to fulfill these sub-functions are in the tabs of the sub-function just like how the other sub-functions in E-Brida work. The tabs are ordered on specifying the information for the function in more detail. In the screen there is a work field and the menu fields. It also contains a summary field at the right, in the summary field information about the other tabs from the item where is worked on in the workfield is displayed. The different functions can be used separate from each other, thus the breeder can decide for himself what he prefers to work with. Therefore the working structure between breeders can be different, but they can use each other's work because although they work differently they can exchange information because data are ordered in the same way.

Goal

When the breeder starts working with the crossing designer the first sub-function is the setting of the goal. To make breeding goals the breeder has to define the goal with basic information[1] and property values. The breeder can select an existing goal or choose to create a new one. When the breeder works further with an existing goal, all the information available for the goal will be displayed and can be changed by the breeder. The breeder can add new activities to the goal or work further with an existing activity. When the breeder want to create a new goal, the same screen as an existing goal will be displayed but then with no information. The breeder can fill in the information and switch between the tabs to specify the information. In the first tab the breeder has to fill in basic information about the goal and save it. Then the new goal is made. After the new goal made the breeder can select the properties in the second tab and give values to the properties (*figure 24*). The information that is set in the first tab will be displayed in summary field. The breeder can select properties from an open folding side panel (like in E-Brida). The breeder can select a property set or single properties. These properties will be visible in the screen and the breeder can set the value and importance value for the properties. While the breeder select the property, down in the working field the option to set a value for that property will appear. After setting the goal by defining the

1. Page 13

properties the breeder can create new activities or select activities within a goal to work with. The activities are the input for material selection.

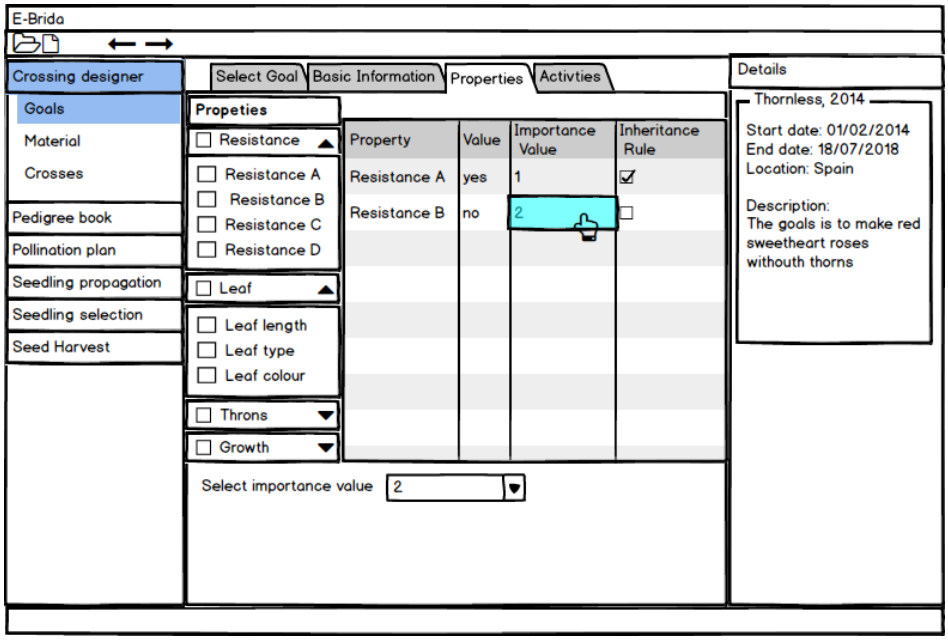


Figure 24. Screen shot of the setting of the properties and the values of a goal in the E-Brida concept.

Material

Activities are already made at the goal and in an activity plant material has to be selected. The output of the goal is an activity within a goal that is the input for the material selection. When a breeder doesn't want to work with goals this step can be skipped. The breeder can start selecting material after creating a new activity (*figure 25*) or select an existing activity. This step is almost the same as the last step of the sub-function goal. When the breeder does work with goals, the activity that is select in previous step is selected automatically to work with. The breeder still can change from activity if he would like to. Activities are the different types of crosses and 'actions' the breeder has to make to achieve the goal. Thus activities together will make the goal. When the breeder selects an activity there will be given a short summary at the bottom of the screen about the activity. At the right in the summary field the breeder can see an overview of what already has been done in the activity.

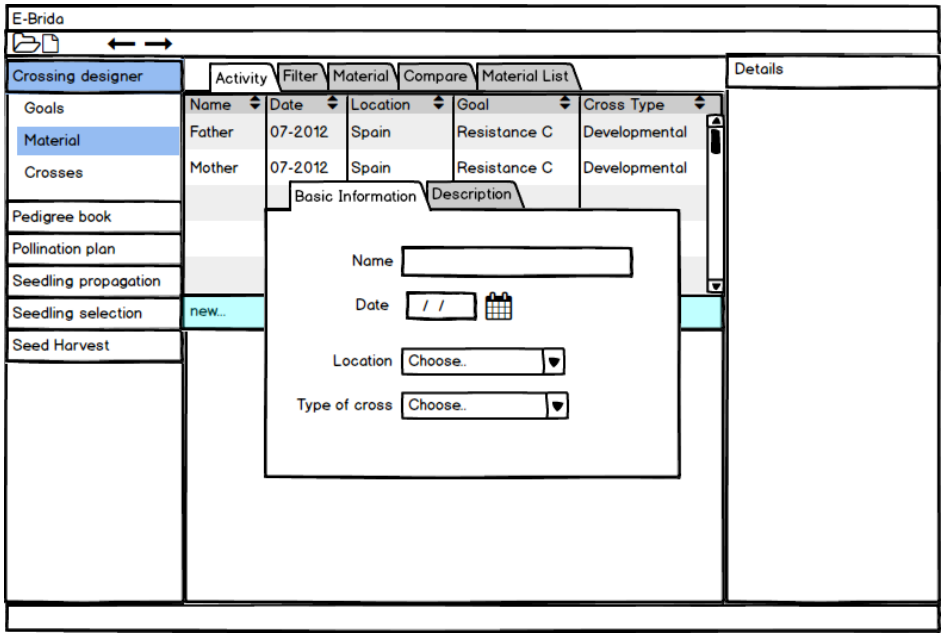


Figure 25. Screen shot of creating a new activity during the selection of material. Will only take place when a breeder doesn't make use of the previous step goals.

When the breeder has selected an activity it has to go to the next tab where the filter will be set. The breeder can choose to work with an existing filter or make a new filter. It is also possible to change an existing filter. When the breeder creates a new filter, filter values for the goal's properties need to be defined and basic filter information[1]. To create a filter a new screen will open like in making an activity. In the first tab the breeder can set basic filter information and in the second tab the filter information for the properties. The filter works exactly as the filter of E-Brida. Although in the filter of the crossing designer the breeder can set inheritance rules[2] for the properties.

After creating the filter the plant material will be selected in the next tab (*figure 26*). At the left side the filter that is used is displayed. Automatically the filter that is selected in the previous tab will be used, but the breeder also can select another filter. The breeder can also make use of multiple filters, by selecting material from the results of one filter and then change filter and select material from those filter results. In the selecting material screen the father and mother plant material can be filtered separately from each other. The breeder also can search for a plant 2 specific for a plant 1. By selecting a plant the breeder can use the option 'filter for' and the filter for the plant material 2 will be adapted with the inheritance rules to the selected plant 1. This can be done also the other way around. In the screen there are two filter lists for plant 1 and plant 2 and in the middle is a list of the selected plant material. Plant material can be selected by dragging it to this list, the material will also stay in the filter list but it will get a vague colour so the user knows that it is already selected.

2. Page 16

1. Page 17

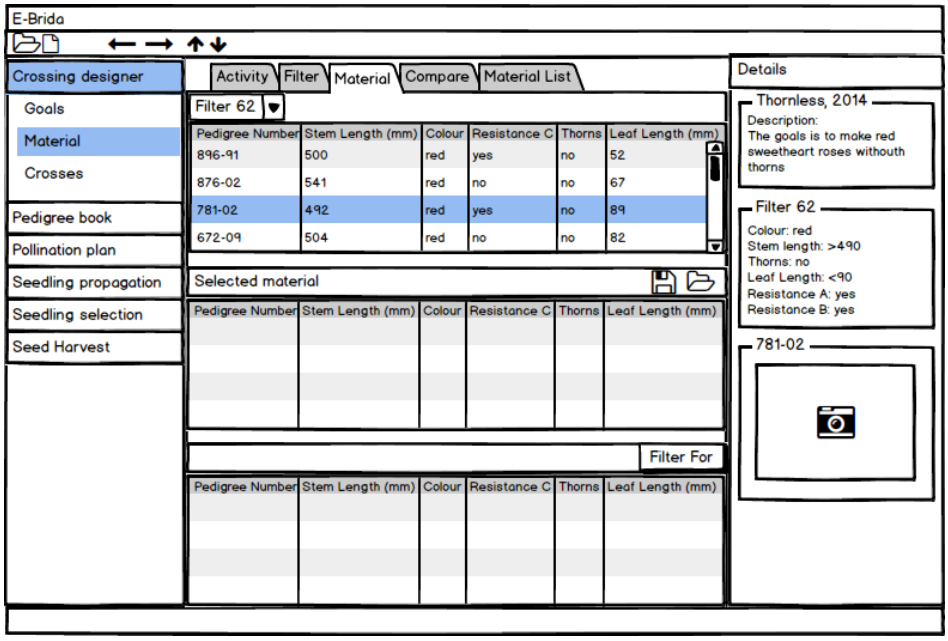


Figure 26. Screen shot of finding plant material and making a material list in the E-Brida concept.

The material list can be saved, but also existing material lists can be opened to work further with. After filtering plant material and before selecting plant material, the breeder can compare plant material. The breeder can select the material which to compare on the properties. This will give a new screen, wherein the breeder can change order of the plant material and the order of the properties to compare them better. From this screen the breeder returns back to the selecting material screen. In the comparing screen the breeder also can select material by ticking the box and returning to the material screen, the material will be placed in the material list by the system automatically. In the summary field the breeder will also see the property information of the plant material that is selected on that moment. In the summary field, notes that are made in the field about the plant material are showed. This is useful information during the selection of plant material, when in the field promising crosses have been identified. The breeder also can place notes during working which can be helpful in the future.

After selecting all the plant material the breeder can create a material list. In the last tab the selected material will be placed underneath each other and the breeder can create a new material list. When a breeder wants to work further with an existing material list he can open a list in this tab and find the crossing scheme of this material list and add material to it. The breeder can also add selected material of a new crossing scheme to an existing material list by saving the list as an addition to an existing list.

Crosses

During the material selection the breeder has made a list with plant material that is interesting to cross because it might give promising results. From all the material that has been selected the breeder has to select the crosses that will be most promising. Therefore the breeder has to make a new crossing scheme. The breeder can create a new crossing scheme and has the opportunity to link it to an activity and use the selected material. When the breeder doesn't make use of the previous steps (goal and material) there will be only crossing schemes saved. When the breeder uses activities, the crossing scheme will be linked to an activity and uses the material that is selected in the activity. When a breeder wants to works with an existing crossing scheme he has to do the same steps as with a new one. The breeder has to select the crosses to preform. For a new crossing scheme the breeder also has to place the material in the scheme. When the breeder creates a new crossing scheme it has to be given a name and linked to an activity, this will be automatically done when the breeder goes to this step from the material step, the material of the activity will be selected. The breeder still can change this, when it isn't correct.

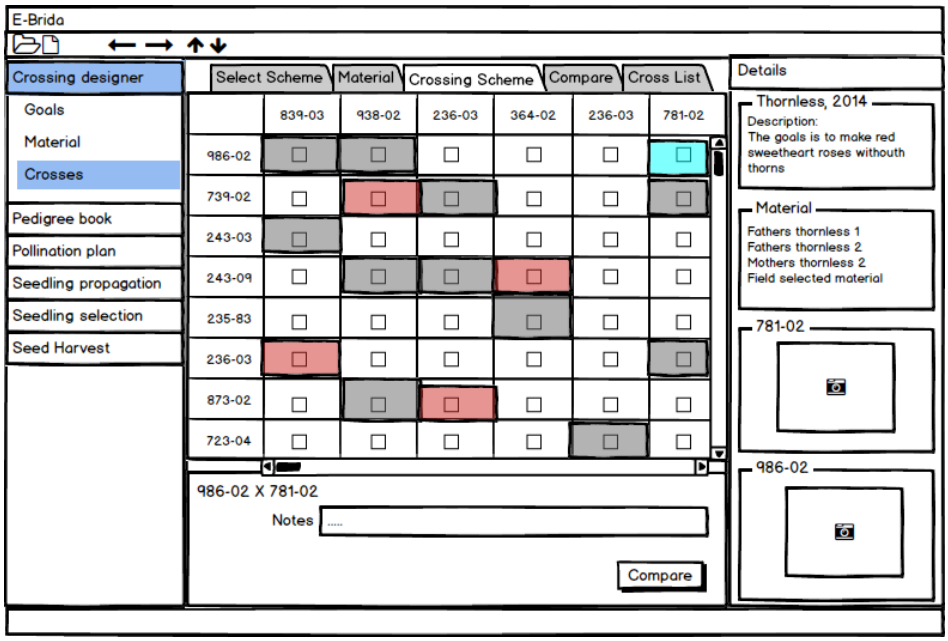


Figure 27. Screen shot of the crossing scheme in the E-Brida concept.

To make the crossing scheme the breeder has to select the plant material list which should be used as fathers and which should be used as mothers. The crossing designer will make a scheme with all possible crosses. In the scheme it is visible which plants has been selected for each other by making these crosses darker grey (*figure 27*). When a cross is made before it will have a red colour. When a cross is made before and the breeder selects this cross, the information about the previous made before cross will be displayed at the bottom of the screen. The breeder also can place notes over there or read previous notes about these cross.

The breeder also can compare the two plants of a cross in more detail by selecting the cross and compare them. A new tab will open with a comparison of the two plants, likely as a comparison during material selection. The breeder can decide there as well if he wants to select the cross, and if he selects it, it will automatically be selected in the crossing scheme as well. In the comparison screen the properties of the two-plant material can be compared, the breeder can order the properties to make the comparison easier.

When the breeder has selected all the crosses to preform, a crossing list will be made. The system will automatically place all selected crosses from the scheme in a list. The breeder has an extra overview of all the crosses that are selected. The crossing designer will also generate the expecting pedigree number for the offspring. The list should be given a name and saved and will be the input for the pollination plan.

Concept 3 – Web Based

This concept is based on the interface structures and functioning of web based software. Web based software is getting more and more popular because the software can be opened in an internet browser and can therefore be used on any device with a internet browser. The advantage for AIP but also for users is that up-dates are done automatically, so that everyone is working within the same version. A problem that AIP now still has is that they have to maintain different versions of E-Brida for different clients of E-Brida, because they are working in different versions. For the users web-based software is usually easier to use than windows-desktop software, because it is technically less intimidating (no installation, updates or configurations are needed[1]).

1. Santos, 2013

The advantage of working in a web environment is that data can be shared more easily between users because all data are stored in a database in the cloud and not on a specific computer. In most plant breeding companies data need to be shared between breeders. To make more promising crosses it is important that the breeders have up-to-date data to work with.

In this concept the crossing designer is built as a platform. For the three different tasks (goal, material and cross) are three different platforms built, which are linked to each other. This is done so that the three different tasks can be used separately form each other and the breeder can apply the software to his own working way. The data will be still useable for breeders with different working ways, because they order in the same way the data. People also can work better together through a platform, because people are all informed at the same time with the same information and have access to the same information. The three main pages are the platforms, where will be returned back to after each step. This main page is a summary of all the functions and data within the task.

The breeder first has to log in with a username and password. The company can authorize people for different functions and different data that will be linked to the log in account. Users go to the website for the crossing designer and log in with their personal account.

Goal

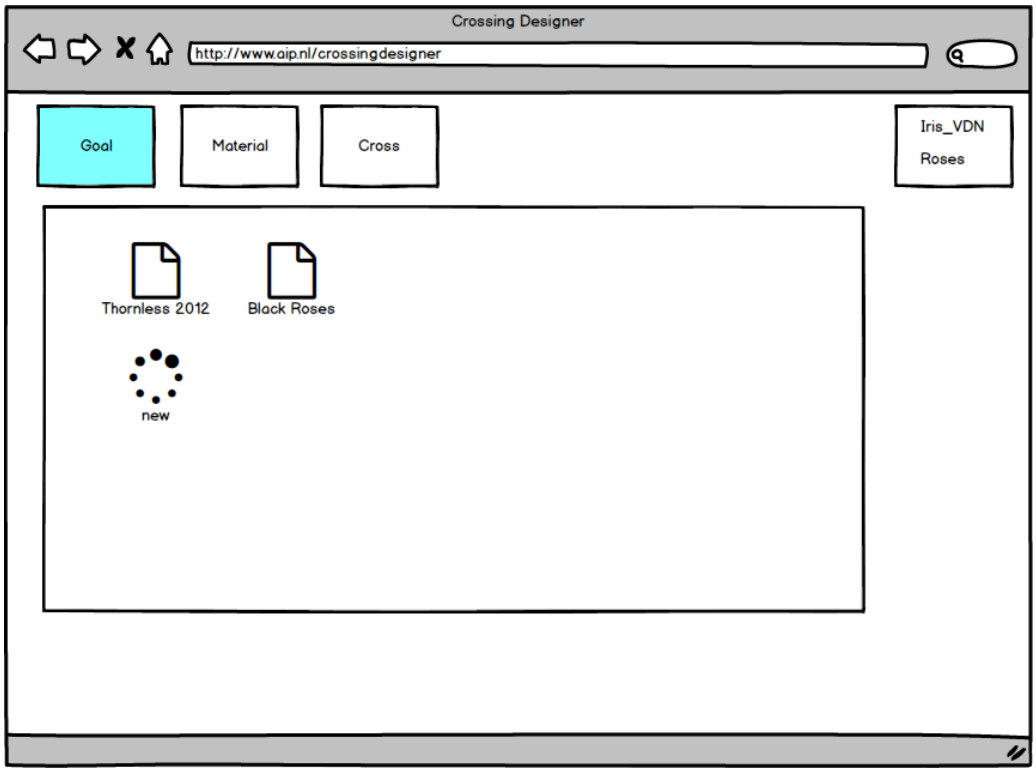


Figure 28. Screen shot of selecting the goal in the web based concept.

When the breeder has logged in, it will have the screen with the three main functions (goal, material and cross) at the top. The breeder can select an existing goal or create a new goal (*figure 28*). When the breeder selects an existing goal the platform will be opened for that goal with all the data. Working with an existing goal is almost the same as making a new goal but there are already data and information available from previous times working with it.

When the breeder creates a new goal, first the basic information has to be set and then the goal is formed. The platform for that goal will be opened and the breeder can fill in the rest of the information. In this platform there are 4 functions, the basic information of the goal[1], the properties for the goal, the activities within the goal and notes (the notes isn't worked out, but this is were notes from the field will be visible in the crossing designer). To complete the goal the breeder will first define the goal with the properties. The breeder can select the properties from a list where all properties are in for the crop where is breed for. A property is selected when the breeder has set a value for it. The breeder can set a value for a property by selecting the property. At the right side of the screen there the setting panel where the breeder can set the value for the property will be opened. This is the same for setting an inheritance rule and the priority of a property. The system will show only the value that is possible for that property. The changes to the properties can be saved.

1. Page 13

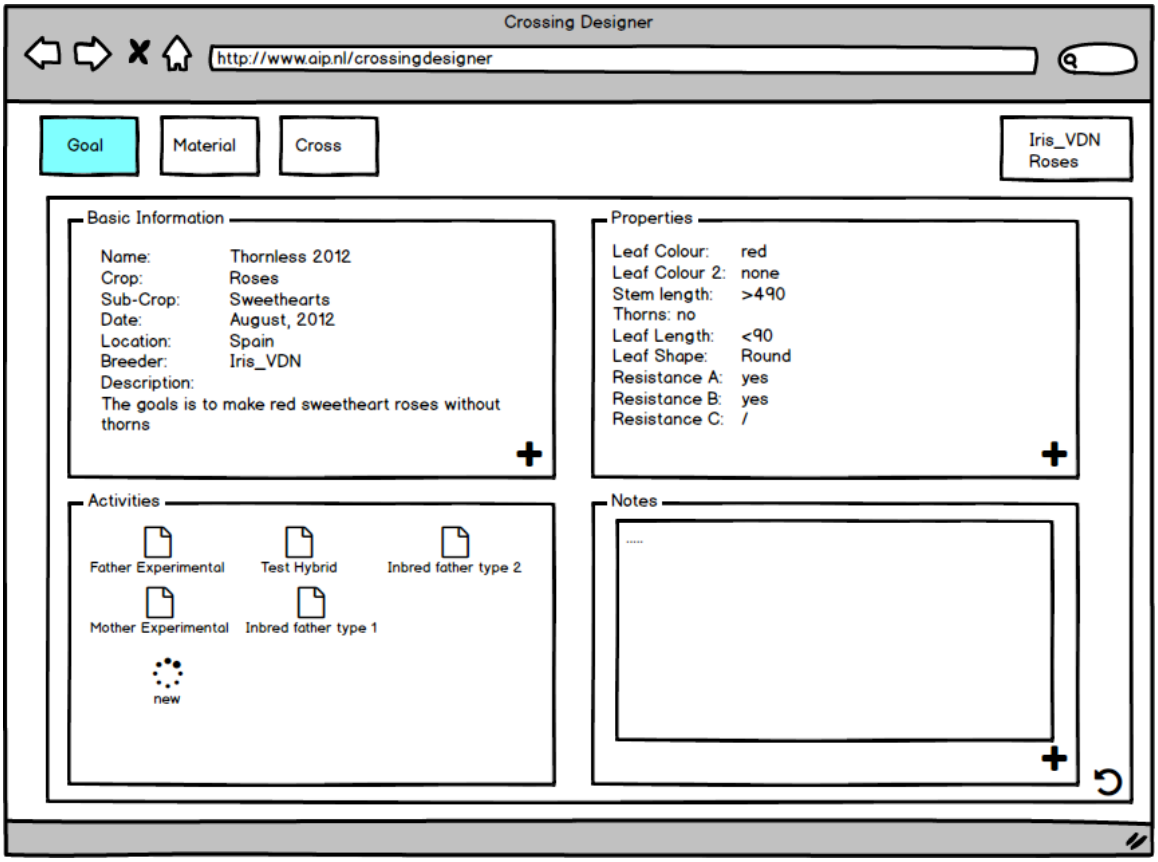


Figure 29. Screen shot of the platform outline of a goal in the web based concept.

At the platform where all the functions are will be a summary of the properties visible that are selected (*figure 29*). In the platform the breeder can create new activities or select existing activities to see what is going on. When the breeder makes a new activity a name has to be set and some information[1] about what kind of crosses is made. The breeder can select an activity and go from there to the next step material or just go to material and select an activity over there.

1. Page 15

Material

The function material can be used separately from the function goal, when the breeder doesn't want to work with goals the breeder can create new activities in material. When the breeder uses goals he can go from selecting an activity in the goal directly to the material platform of that activity. When the breeder just goes to material, the breeder first has to select an existing activity to open the platform of an activity or create a new activity. For the new activity the breeder has to set a name and some information of what kind of cross he is going to make. Material is selected for an activity, or material list can be exchanged between activities with the import and export button. When an activity is selected the platform will be opened. In the platform there are 4 sub-functions; activity information, material lists, filters and notes.

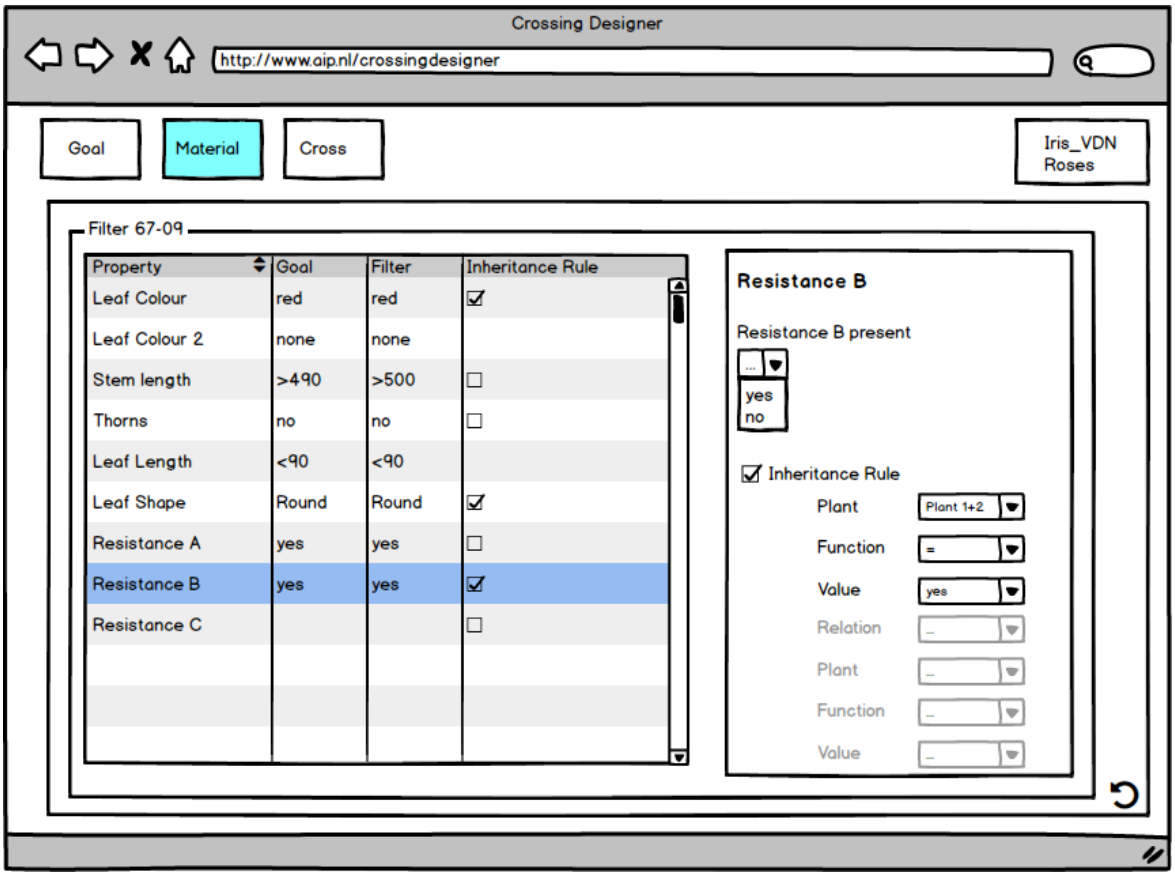


Figure 30. Screen shot of setting a filter in the web based concept.

The breeder will first set a filter, or uses an existing filter. The breeder can import filters from other activities or change filters of the activity. To set a filter, the breeder has to set values for the properties. All the goal's properties are used and when there is not worked with goals all the properties of the crop will be visible. To set the filter value for a certain property, the property needs to be selected, at the right the setting panel of the value for a property is opened. The breeder also can apply the inheritance rules[1] on the filter and can even add inheritance rules (*figure 30*). Filters can be saved, and when changes are made to a filter they can be saved as a new filter or saved over the existing filter.

1. Page 17

After making the filter the breeder goes back to the platform and will start selecting the material. The breeder has to select the filter he wants to use. There are two filter fields, so that the breeder can filter potential partner plants for a selected plant. By selecting one plant the breeder can use the option 'filter for' and then the filter will use the inheritance rules to find another a partner plant. The breeder can select the plants, which he wants to use to make crosses. These are saved as a material list, which will be visible in the platform. The breeder can select material lists from the platform to make changes to the material list. The breeder can also use different filters for one material list, or change the filter while creating a

material list. The breeder will go directly to the filter settings to change the filter. During the selection of the material the material is presented with the properties so the breeder can compare plants and their properties with each other to select the best plant material. The selected material can be saved as a material list, which will be the input for the making of the crossing scheme. A material list is made from the material selection. The selected material can be saved as a new material list or added to an existing material list.

Crosses

The material list is the input for the making of the crossing scheme. Breeders still work within an activity when they are making the crossing scheme. The user can use the function crosses separately from the function material. The breeder can go from the function material to the function cross, and then the activity used in the function material will be opened in the platform of cross. The breeder still can change from activity. The platform contains four functions; material lists, crossing schemes, crossing lists and activity information (*figure 31*).

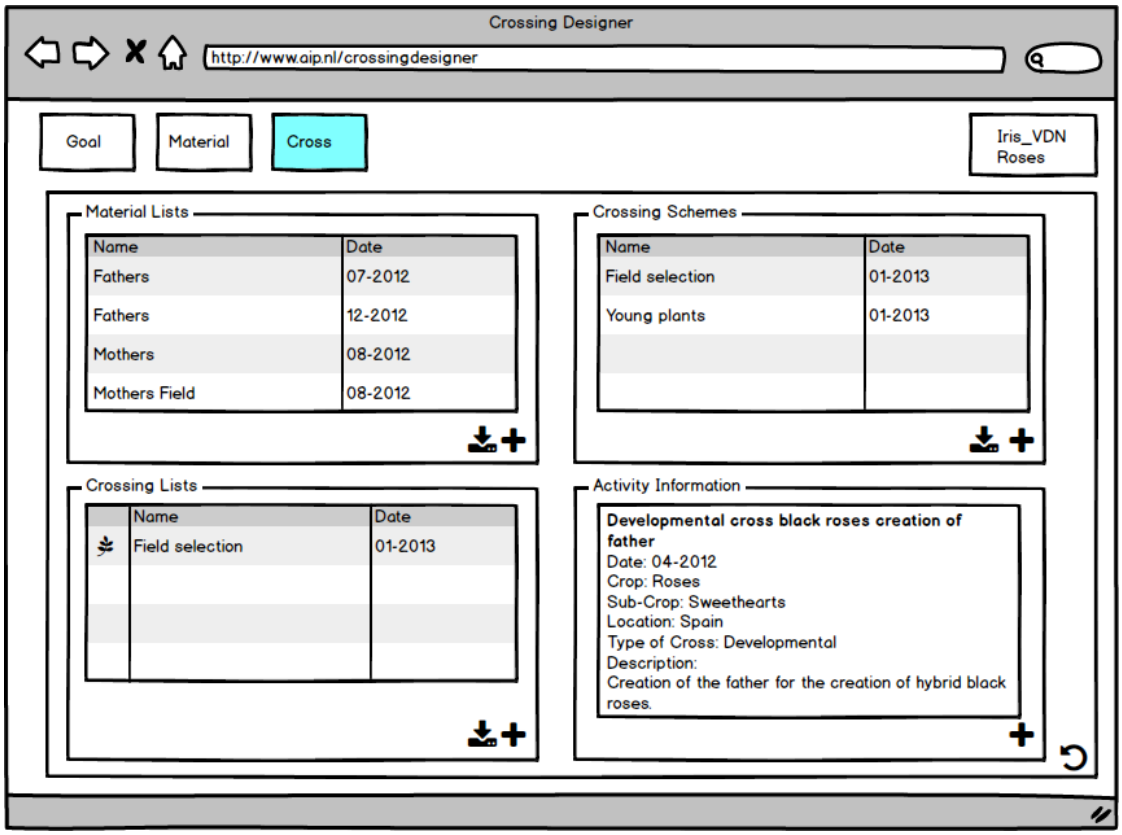


Figure 31. Screen shot of the cross platform of the web based concept.

During the material selection the breeder has made a list with plant material that is interesting to cross because it might give promising results. From all the material that has been selected the breeder has to select the crosses that will give the most promising offspring. Therefore the breeder has to make a crossing scheme. When the breeder doesn't use the other functions, the crossing schemes will be not part of an activity. The breeder can work further with an existing crossing scheme or create a new crossing scheme. When a new crossing scheme is created the breeder has to set the name and has to make the material lists himself, or he can export material lists from Excel. A lot of breeders make use of Excel to make material lists. When worked with the previous steps the activity is the platform of the crossing scheme. The breeder can work further with an existing crossing scheme of the activity or create a new crossing scheme. When the breeder creates a new crossing scheme it has to be given a name and linked to an activity, this will be automatically done when the breeder goes to this step from the material step, the activity of the material will be selected. The breeder still can change this, when it isn't correct.

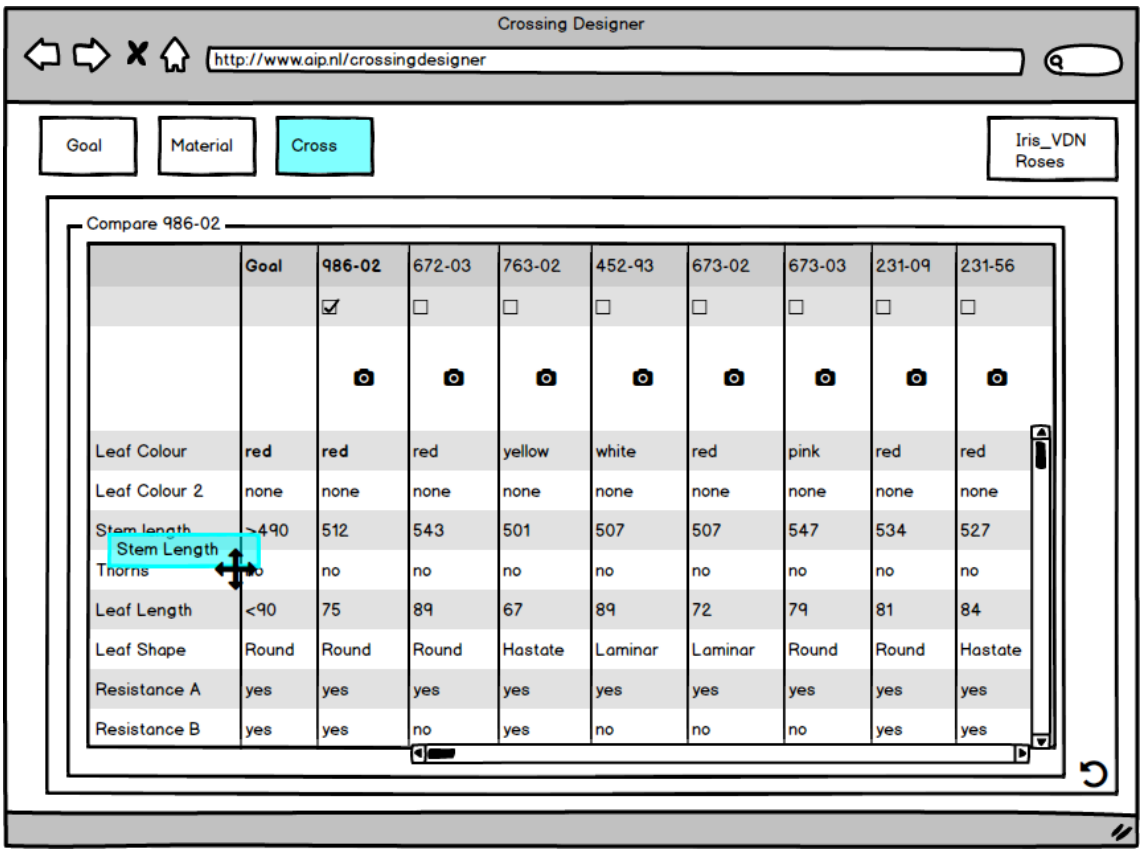


Figure 32. Screen shot of comparing multiple crosses in the web based concept.

To make the crossing scheme the breeder has to select the plant material list which should be used as fathers and which should be used as mothers. The crossing designer will make a scheme with all possible crosses. The scheme is a matrix with horizontally plant material 1 and vertically plant material 2. The scheme is almost the same as in concept 2. In the scheme it is visible which plants has been selected for each other by giving this crosses a dark grey colour. When crosses are made before they will get a red colour. For every cross is a small number in the scheme visible which shows the amount of available material.

The breeder can open the information of a cross by clicking the information button. Then a comparison of the two plants will open. The breeder also can select one parental plant and compare it with all the possible candidates. In both cases a comparison screen will be opened. In this screen the breeder can select crosses and can return to the scheme. In the comparison screen the breeder can order the properties and plants, by dragging it to the right place, to get a better overview (*figure 32*).
When the breeder has made a selection, a crossing list can be created. In this list all the selected crosses are placed and the breeder has an extra overview of all the crosses that has been selected. The crossing designer will also generate the expecting pedigree number of the offspring. To use the crossing list in the pollination plan in E-Brida the breeder has to select the crosses which to make from the crossing list and give this as input to E-Brida. The breeder will have an extra check or the best crosses are selected. When a crossing list is used in a pollination plan it will have the E-Brida sign in front of it. The breeder then knows where to work further with and what is done.

Conclusion

Three concepts are worked out, in the three directions resulted from the idea phase. For each concept a prototype is made in Balsamique, a software programme which helps creating software mock ups. The prototype gives a visual idea of how the concepts will look like. The prototype is partly functional to get idea of how the crossing designer works and to do user tests with it.

The first concept was the step-by-step structure concept. This concept is focussed on guiding the breeder through the process of making crosses. In the concept al steps to make a crossing scheme are split up and need to be walked through to create the crossing scheme. The breeder knows exactly what to do and what the next step will be.
The second concept was the E-Brida concept. This concept is based on the current AIP breeding software E-Brida. The crossing designer will become part of E-Brida, and this concept is focussed on integrating the crossing designer into E-Brida. The crossing designer has the same structure and user interface as E-Brida. The breeder can use the crossing designer as a separate function in E-Brida, just like the pedigree book function in E-Brida. The crossing designer collaborates with the other functions in E-Brida, so that the whole breeding process is supported within E-Brida.
The third concept is the web-based concept. This concept is focussed on making a web-based software of the crossing designer. This concept makes use of a platform for each of the three main functions. The functions in the platform are coupled to each other, but can be used separate from each other as well. Within a function the breeder has supporting tools that he can use for the breeding process. With the platform the breeders can have different workflows but all the breeders use the same data flow and therefore breeders can work better together. Breeders also can communicate with each other over a platform.

Testing

1. Page 55

Three concepts have been created and described[1]. These concepts must be analysed to decide which concept will be used further in the development of the crossing designer. The analysis also will give information about the weak points of the concept that need to be changed in order to get the best final product. During the analysis the concepts are compared with the requirements that have been defined for the crossing designer[2] and a user test is done. To do a good user test it is important to choose the right method of testing, and define the protocol of the test. This will give reliable results that are useable for analysing the concepts.

2. Page 39

Method

The choice of a testing method depends on the information the results of the test should give. In this case the results of the test should give information about how a breeder experience the support of the concept in the process of making crosses. The results have to show which concept will be the best to work further with, and how this concept can be optimized.

Scenario Testing

3. Kaner, 2013

There is chosen to make use of the scenario testing method[3], because the results contain the experience of users with the different concepts. For this method a scenario is written of using the product, that the user will preform. The scenario is a guideline for the user, of how to use the product. During the test the test person will experience the product in the situation it is used for. Making use of this method for the crossing designer has multiple advantages.

- The user is using the actual product, and can experience how it is working with the crossing designer.
- The user will learn the product, the crossing designer is a new tool for the user and therefore they need help to understand how it works. With the scenario testing the user will have a guideline of how the product should be used.
- The scenario includes all the important features of the crossing designer. It makes sure that the user won't forget or miss things of the crossing designer that could influence the users experience.
- All the users will test the crossing designer in the same way, and experience the same features. When there is no scenario results might differ from each other because users have done something different.

Besides these advantages another advantage was that only features of the scenario has to be built as a prototype.

Protocol

A protocol describes the activities, requirements and evaluation of a test. A protocol is important to make sure tests are done in the correct way and reliable results are obtained. A protocol will help in doing the test each time the same, so that results can be compared. Important aspects of the protocol of scenario testing are; the scenario's, the test persons and the scoring method.

Scenarios

For the three different concepts a scenario[1] for testing the prototype is written. Chosen is not to write one scenario useable for all the concepts but to write for each concept a scenario, this to make sure that the users can see the differences in the features between the prototypes. In the three different scenarios the main story is the same, so that the user can compare the functioning.

1. Appendix IV

The test person will test all three scenarios. The order of the scenarios has effect on the results of the user test, because there is a learning effect during the testing of the three concepts. The crossing designer is quite a new product, so the concept that is tested first will prepare the test person already for the next concept that is tested. For the step-by-step structure concept the main focus is supporting the understanding and use of the crossing designer optimally, while for the other two concepts the focus is more that people get support in the breeding process and that they will learn to use the product after several times. Therefore the test persons are divided over two groups; the people who have the scenario of the step-by-step structure first and the group who have one of the other two scenarios first. For the factors that could be affected by the order of testing, the scores of the two groups need to be taken separately to take the learning process into account before taking any conclusions.

Test persons

The user test is done with a group of 16 people. This group can be divided in two type of stakeholder, 10 breeders who are the final users of the crossing designer and 6 producers of the crossing designer who are the people of AIP. There has been chosen to include the producers in the user test to get information about the technical aspects of the concepts. The crossing designer is still in the early stages of the developing process, and there hasn't been looked at the technical possibilities. Besides that the people at AIP work closely together with a lot of breeders and have a lot of knowledge about the interests of breeders in the crossing designer, which they can share in the user test. Testing the people of AIP will represent the interest of a big group of users.

Scoring

Testing is done to determine which concepts fits bests with the consumer needs and should be developed further with. The concepts can be

2. Page 39

compared with the requirements[2] set for the project. Part of the requirements can be checked without a user test but some not. The requirements that should be tested with the user test are the requirements that are related to experiencing the product. Besides the checking the concept with the requirements, the results of the user test also should give information about whether the crossing designer supports all steps in the design process, which concepts workflow best fits with the breeding process and the positive and negative aspect of the concepts.

To get these results the test person is analysed when making the test, and a questionnaire[1] is held during an interview after testing. There has been chosen to do an interview because the crossing designer is still in the developing phase so there are still a lot of things variable that can be better discussed during an interview. During the interview there is also gained more understanding of why the user has this opinion, and understanding that is very important in the early stages of the design process because it will help with the further development of the crossing designer.

1. Appendix V

Results

The results of the test are separated in two parts, the scoring results[2] that are the result of how the users have scored the different concepts and the discussion results[3] that are the results of the comments the users have been given on the concepts during the interviews. The results have been analysed to take conclusions about the concepts and decide with which concept to work further. From the scoring results can be concluded that most users prefer the Web-based concept (10 out of 16), but to understand this and support this we have to take a look at the other scores to conclude that the Web-based concept is the best.

2. Appendix VI

3. Appendix VII

Scoring results

Within the test there is made a difference between the orders in which the concepts are tested. The test persons are divided over two groups; the people who have the scenario of the step-by-step structure first and the group who have one of the other two scenarios first. This order is important because the order could affect the experience of a concept.

Time

The time the user needs to complete a scenario is measured. The process of learning affected by the order of testing the concepts should be taken into account. For each scenario and the order the scenario was done the average time of the test persons to complete the scenario was calculated *(table 1)*.

	Average time (min) start concept 1	Average time (min) start concept 2	Average time (min) start concept 3
Concept 1	11.5	10.6	10.0
Concept 2	8.6	13.2	10.3
Concept 3	7.7	8.6	12.0

Table 1. Average time, for each order of testing.

The results show that the concept that was tested first took the most time to complete the scenario, which confirms the expectation that the order wherein the scenarios are tested affect the time to complete the scenario. On average the time to complete the scenarios of concept 3 is the shortest. It takes the least time to complete the scenario of concept 3, compared to the other concepts when they are tested first and when tested not as first. Therefore scenario 3 can be considered as a concept that is easy to use, but this depends on other scoring results as well.

Mistakes

The mistakes the user made in test are counted. The process of learning affected by the order of testing the concepts should be taken into account, because the expectation is that when already a concept has been tested before the amount of mistakes for the next concept to be tested will be lower because there is knowledge about the product. The average amount of mistakes is calculated for each concept and the order of the concepts *(table 2)*. The amount of mistakes gives information about the guiding of the product during the process.

	Average amount of mistakes start concept 1	Average amount of mistakes start concept 2	Average amount of mistakes start concept 3
Concept 1	6.3	5.4	5.6
Concept 2	7.3	10.6	7.6
Concept 3	6.6	6.4	8.0

Table 2. Average amount of mistakes, for each order of testing.

The results show that on average for concept 1 the fewest mistakes are made, independent from which concept is tested first. This can be explained by the fact that concept 1 was designed to tell the user what to do. From the results there can be concluded that concept 1 directs the user through the steps the best. For the concept 2 there are made on average more mistakes than for concept 3. There are only made more mistakes in concept 3 when it is tested first, but it is still less than for concept 2. From the results there is support to conclude that concept 2 is the least clear concept, but the conclusion depends on the results of the question scores.

Questions

During the test the users could ask question for help. The amount of questions that are asked for each concept are taken into account, because it may affect the mistake score and it gives information about how well the user understands the product. The scores of the questions are expected to be in line with the scores of the mistakes. The scores have to be compared to make a conclusion about the directing of the product. For each concept and the order of testing the average amount of questions asked by the user are calculated *(table 3)*.

	Average amount of questions start concept 1	Average amount of questions start concept 2	Average amount of questions start concept 3
Concept 1	8.1	6.6	6.6
Concept 2	9.1	10.8	11.4
Concept 3	6.1	7.9	7.0

Table 3. Average amount of questions, for each order of testing.

The results show that the amount of questions asked during the testing of concept 2 was on average the most, which is in line with the amount of mistakes made for concept 2. From this results there can be concluded that concept 2 gave the least direction and was the hardest to understand by the users. It also explains why it took the users more time to complete concept 2 than the other concepts. For the concepts 1 and 3 the amount of questions asked was almost even, although for concept 1 fewer questions had been asked than for concept 3 when the concept was not tested first. From the results there can be concluded that concept 1 is slightly easier than concept 3, which isn't surprising because concept 1 is designed with the purpose to guide the breeder.

Clearance

The users have been asked to order the concepts on how they experienced the clearance (which means that the user knew what to do each step and after the step). They had to order the concept from most clear (score 1) to less clear (score 3). The users had to score the concepts after they tested all three concepts, therefore the order of testing doesn't need to be taken into account. The average score for each concept is calculated, but for analysing it is also important to look at which scores have been given how many times *(table 4)*.

	Amount of 1 scores	Amount of 2 scores	Amount of 3 scores	Average score
Concept 1	6	7	3	1.8
Concept 2	3	6	7	2.3
Concept 3	7	3	6	1.9

Table 4. Amount of scores that are given for clearance and the average score.

From the results the conclusion can be taken that concept 2 is the least clear, because the average score was obviously lower than the average score of the other two concepts. The average scores of concepts 1 and 3 are almost the same (1.8 for concept 1 and 1.9 for concept 3). The scores for concept 3 stick out because they get the lowest score almost as often as the highest score. There can be concluded that the opinion about concept 3 is spread out between the users. From the results the conclusion can be taken that concept 2 is the least clear concept.

Opportunities

The users have been asked to order the concepts on the opportunities the concept has to make a crossing scheme (which means how they think the concepts creation of a crossing scheme is applicable for their work). They had to order the concepts from the one with the most opportunities (score 1) to the one with the least opportunities (score 3). The users had to score the concepts after they tested all three concepts, therefore the order of testing doesn't need to be taken into account. The average score for each concept is calculated, but for analysing it is also important to look at which scores have been given how many times *(table 5)*.

	Amount of 1 scores	Amount of 2 scores	Amount of 3 scores	Average score
Concept 1	1	5	10	2.6
Concept 2	5	5	6	2.1
Concept 3	10	6	0	1.4

Table 5. Amount of scores given for opportunities and the average score.

The results are quite clear to make a conclusion. The opportunities in concept 1 are the worst, because of the lowest average score. This can be explained by the fact that concept 1 has no freedom in making decisions which affects the score for opportunities. Concept 3 had the highest average score and has the most 1 scores. The conclusion can be taken that concept 3 has the most opportunities to make a crossing scheme.

Complexity

The users have been asked to order the concept on complexity. The users had to order the concepts form most complicated (score 1) to less complicated (score 3). The users had to score the concepts after testing all three concepts, therefore the order of testing doesn't need to be taken into account. The scores of complexity are expected to be in line with the scores of questions and mistakes, because they all give information about the difficulty of the concepts. The average score for each concept is calculated, but for analysing it is also important to look at which scores have been given how many times *(table 6)*.

	Amount of 1 scores	Amount of 2 scores	Amount of 3 scores	Average score
Concept 1	0	3	13	2.8
Concept 2	9	6	1	1.5
Concept 3	7	7	2	1.7

Table 6. Amount of scores given for complexity and the average score.

The results show that concept 1 is the least complicated concept, which is in line with the mistake and questions scores. For the concept 2 and 3 the average scores are close to each other (score 1.5 for concept 2 and score 1.7 for concept 3), which is also in line with the mistake and question scores. For concept 3 the scores 1 and 2 are given evenly while for concept 2 the score 2 is given twice as much then score 1. There can be concluded that concept 2 is the most difficult concept, which is surprising because you would expect that concept 2 which is in line with E-Brida that is an existing software that is used by breeder would be easier to use, because the test persons know this product.

Functional

The users have ordered the different concepts on functionality. They had to order the concept from most functional (score 1) until least functional (score 3). Functional is about if the product will support them during the breeding process in a good way. This is an important aspect, because it is the main goal of the crossing designer. The average score for each concept is calculated, but for analysing it is also important to look at which scores have been given how many times *(table 7)*.

	Amount of 1 scores	Amount of 2 scores	Amount of 3 scores	Average score
Concept 1	0	6	10	2.6
Concept 2	7	6	3	1.8
Concept 3	9	4	3	1.6

Table 7. Amount of scores given for functionality and the average score.

The results show that concept 1 is the least functional, because it had the lowest average score (2.6) and it scored 3 the most times (10 out of 16). In concept 1 the focus was on the directing of the user through the software, these results show that users don't want to be guided through the steps. For the concept 2 and 3 the average scores are close to each other (score 1.8 for concept 2 and score 1.6 for concept 3), these two concepts both have more freedom in the process and therefore have more functions. From the results there can be concluded that concept 2 and 3 are more functional.

Useable

The users have ordered the different concepts on usability, by ordering the concepts from most useable (score 1) until least useable (score 3). The scores will give information about which concepts structure is preferred. The users had to score the concepts after they tested all three concepts, therefore the order of testing doesn't need to be taken into account. The average score for each concept is calculated, but for analysing it is also important to look at which scores have been given how many times *(table 8)*.

	Amount of 1 scores	Amount of 2 scores	Amount of 3 scores	Average score
Concept 1	4	7	5	2.1
Concept 2	4	5	7	2.2
Concept 3	8	4	4	1.8

Table 8. Amounts of scores given for usability and the average score.

The average score are close to each other. Concept 3 has been given the most 1 score (8 out 0f 16). There can be concluded that most users prefer concept 3. For the concepts 1 and 2 it is almost impossible to decide with these results which concept is preferred more.

Structure

The users have described what they thought the structure of the 3 concepts was, there description has been turned into scores. For a correct description the concept get a score 1 and for a wrong description a score 0. This has been done to decide whether the user understand the concepts, if the preference of a user for a specific concept is reliable and to determine the usability. When the user understands the product, the product will be used more efficiently. When the user doesn't understand the product, it is harder to use the product. The average score for each concept is calculated, but for analysing it is also important to look at which score has been given how many times *(table 9)*. The users had to describe the structure of the concepts after they tested all three concepts, therefore the order of testing doesn't need to be taken into account.

	Amount of 0 scores	Amount of 1 scores	Average score
Concept 1	0	16	1
Concept 2	8	8	0.5
Concept 3	7	9	0.6

Table 9. Amounts of scores given for the structure understanding and the average score.

From the results the results there can be concluded that concept 1 has a clear structure, because it only has 1 score. This isn't surprisingly because the structure of concept 1 was step by step, so the users were taken by the hand through the software and didn't have to explore it by themselves. For the concept 2 and 3 only half of the users could explain exactly what the structure of the concept was. For concept 3 is not that surprisingly because the structure is totally new, while for concept 2 the structure is taken from E-Brida and you would expect people to explain that. It does explain why breeders have trouble in using E-Brida optimally[1].

1. Appendix III

Amount of steps to create a crossing scheme

Users had to score the amount of steps they had to make to create a crossing scheme. This is done when the user thinks too much steps must be taken in the concept the concept is too simple and when they missed steps the concept is experienced as difficult. The user could give the following score between 0 (too less steps) and 2 (too much steps). The users had to score the concepts after they tested the concepts, therefore the order of testing doesn't need to be taken into account. The average score for each concept is calculated, but for analysing it is also important to look at which scores have been given how many times *(table 10)*.

	Amount of 0 scores	Amount of 1 scores	Amount of 2 scores	Average score
Concept 1	0	5	11	1.7
Concept 2	5	7	4	0.9
Concept 3	3	10	3	1.0

Table 10. Amount of scores given for the amount of steps and the average score

Concept 3 has an average score of 1.7, the amount of score 2 is very high and it doesn't have any 0 scores. The results show that the users have scored this concept as too much steps, which means that it takes too many steps to get to the goal and indirectly means that the concept is too easy. The concept has a step-by-step structure, whereby the software will make for every action a separate step. In the other two concepts the user was free in deciding which steps to do. The average scores of these concepts was around 1, which means that users thought it was enough steps to do. Concept 3 has mostly 1 scores, while the scores of concept 2 are more distributed, therefore there can be concluded that the amount of steps in concept 3 is more preferable by the users then of concept 2.

Conclusion

The scoring results show that concept 1 is the easiest concept to use, which isn't surprisingly because in this concept the software tells the user what to do. For the users this is the first time working with such software, and therefore this concept that explains them everything will be preferable. Although for the scores that are more related to working with the software (amount of steps, structure and opportunity), concept 3 is preferable. For concept 3 the user first needs to get used to the software before they can work fast with it, but the users have noticed this and taken it into account with scoring because otherwise the scores probably would have been lower. The results of the discussion should be taken into account to understand the scores of the concepts and decide which concept should be chosen to work further with.

Conclusion on discussion results

At the end of the test the users had the opportunity to give comments on the three concepts and explain what kind of end product they would like to see. An interview was done to make sure the comments were understood in the right way. These results are not scores that can be analysed with statistical numbers, it are opinions that should be taken into account to explain the scoring results. The users have described the positive and negative point of the three concepts, but also gave tips on how concepts could be integrated into each other.

Positive points

The positive points are the things of the concepts that the users have experienced as something good and what should be seen back in the final product. There were some general positive points of the crossing designer which count for all the three concepts, these points will always come back no matter which concepts will be chosen to work further with. These positive points were mostly about that the breeder was supported by the functions of the software during the making of crosses.

The positive point of concept 1 was that it was very clear what the breeder had to do, and that it was hard to make mistakes. In the selection of the crosses the breeder had to look at each cross in detail. The crosses were represented in a list but this list didn't give enough information to determine or a cross should be selected. Each cross had to be looked at in detail and before deciding whether to make it or not. It is quite time consuming but it makes sure that the breeder would not miss any information and makes a wrong decision. Some breeders really preferred the representation of the crosses in a list.

For concept 2 the positive point was that it looked like E-Brida so the user is already used to it and therefore it was easy to create your own workflow in it. The advantage of the tabs in the filter was that you could only fill in important information to make a cross or to go further in detail and fill in the other tabs, but that you could make the choice yourself and that the system didn't forced you to check out all possibilities.

For concept 3 the positive aspect is that you could create your own workflow and that the software was adapted to that workflow. The advantage of working on a platform is that is more in line with modern software and it makes working together with other breeders easier.

Negative points

The negative points are the things of the concepts that the users have experienced as something bad and what should be changed to get a good final product. There were some general negative points about the three concepts of the crossing designer, therefore a new solution for these negative points should be created. Most negative points were about things that were missing in the concepts.

A negative point is that there is no possibility to create new properties, and that new properties should be placed into the notes, but it isn't possible to filter within the notes. In the final product it should be possible to add new properties and filter within the notes. A thing that is missing in the crossing designer is the status of goals and activities. Another negative point is that when material lists are made there can be searched for parental plant material combinations, but that these matches don't comeback visible in the crossing scheme. An idea to solve that was to select parents and make sub lists within the material list of matching parents.

For concept 1 the main negative point was that this concept was too limited, everything has to be done in a certain order and to recover mistakes or make small changes, takes a lot of time because all steps need to be repeated. During the selection of properties there is the possibility to make property sets as well, but the users don't understand this. It is a combination of two functions in one, but they don't go along together. The making of property sets needs to be a different function.

For concept 2 the negative points are mostly about the visual information on the screen. In this concept the information, which is visible, is already determined, while this differs for each user. Also it isn't visual where the user is in the process that may cause that important steps are skipped while the user isn't aware of it.

For concept 3 a negative point is that information only can be given by value selection and not by typing in, which is probably faster. Other negative point is about the three level platform structure, that not all information is available on each level and that there always need to be returned to the main platform to switch functions.

The concept that is chosen should be analysed on the negative points and there should be looked for a solution. Also negative points of one concept can be applicable for the other concepts, but it might be that users haven't noticed it, so therefore analysing is important.

Conclusion

The discussion results show that concept 1 doesn't support the breeder because it is too limited in functioning. Concept 2 and 3 have more opportunities and will support the breeder better during the making of crosses. Although aspect of concept 1 should be taken into account in the final product, such as the structure which could be used as a wizard function in the crossing designer, and for critical points this structure should be kept, to make sure nothing will be forgotten or mistakes are made. As for concept 2 and 3 the breeders should be able to create personal settings on which information they want to have visible in the screen and have the opportunity to choose between a list or matrix representation of the crossing scheme. This will improve the positive point of these concepts that breeders can have their own workflow.

Conclusion

The raw score (asking the users which concept they preferred) resulted in concept 3, was analysed with the results of the discussion and the scoring results. These results support that concept 3 is the best to go further with.

For concept 1 the scoring results and the discussion results showed that the concept is very clear and easy to use. There are low amounts of mistake scores and time scores, and the users pointed as positive points also out that it was clear what to do. The critic on concept 1 was that it had too many small steps and therefore the user didn't have any freedom to create an own workflow, what explains the low score for amount of steps taken to create a crossing scheme. The user prefers a product that has more user freedom. Although the comments on concept 2 and 3 that have more freedom were that important steps might be missed or forgotten in a personalised workflow. Therefore on the critical parts during the making of crosses, which is the selection of the crosses, the step-by-step structure should be maintained. This means that all the crosses that are made should be analysed before deciding to make them or not, which will result in making less mistakes (the amount of mistake score was much lower for concept 1 then for 2 and 3). Another thing of the step by step structure is that during the making of crosses a lot of data are used, when

all these data have to be analysed separately in the crossing designer it takes a lot of time. In the current software E-Brida this is already experienced as a negative point, because are made one by one and therefore the users use excel, because there multiple crosses can be made at the same time. The goal of the crossing designer is that it will help the breeder and that the breeder will not use other software as well. Although for understanding a product it is nice to do everything step by step because you will see all the functions and you will be guided through the software.

For concept 2 the discussion showed that it was a positive aspect that the concept looked like E-Brida because users are known with this software. Positive was that it makes a difference between basic information and detailed information with the tabs, and this is important for the breeder in creating their own workflow. Although the scoring results showed that the users actually did not understand the structure of the concept that well. They could not explain the tab structure and the time of completing the task wasn't lower although they already know this software. This could be caused either by the fact that the concept isn't totally in line with E-Brida or that E-Brida isn't fully understood by the users. The main disadvantage of the concept was that people were not aware where in the process they were and what/why they were doing things. From this concept it is clear that users like to work with products that are integrated with each other, when the functions of the product are closely related. Therefore for the crossing designer it is important that it is adjusted to E-Brida.

For concept 3 the discussion showed that the users preferred the platform based software structure, because it supports the collaboration between breeders. During the interviews it became clear that breeders do value good exchange of data. The final product should be able to change data easily between users.

Another point users pointed out was displaying the status of an activity or goal. There has been looked to integrate this but in earlier research there was already found out that it would be too difficult and therefore it is left out of this project. When this was discussed with the users they could imagine that it is hard, but that makes there job difficult that it is hard to predict the status of reaching the final goal.

The results showed that concept 3 is the best to work further with, although it needs some changes. Positive aspect from the concept 1 and 2 need to be integrated in this concept, and for the negative point other solutions needs to be created.

Recommendations

The testing results gave the final conclusion to develop concept 3 further. Before concept 3 becomes a product, which can be placed on the market, it still needs some changes. To make these changes AIP has to do some further research on how to develop the crossing designer. The testing results showed negative aspect of the concept that should be resolved and showed the positive points which should be maintained and why this concept has been chosen.

Concept 3 was the web-based concept, this concept worked with platforms. The three main functions were the three main platforms in this concept. In each step the sub steps to full fill this function were functions within the platform. The advantage was that all the information, which was needed for the function, was available at one page, and that working with the information could be done from one main platform. The advantage of working with a platform was as well that breeders could share their data by working within the same data set. For this concept there still need to be made some changes and some functionality has to be added. The workflow wasn't fully perfect, it still takes too many steps to switch from function, and the input of data should be changed as well.

When AIP wants to develop the crossing designer further from concept 3 they still have to do research. To develop the crossing designer further they should do the following steps; they need to take a closer look at the aspects of the concept and write down which they want to maintain and which they want to change. From the other two concepts they should write down the positive points and look how they can apply them on concept 3. AIP also need to take a look on how current field observations can be used in the crossing designer. The current application they have made could be linked to the crossing designer. During this project the application was still in development and therefore it was hard to do research on it.

AIP also has to make decision on how they want to relate the crossing designer to E-Brida. When they have made this decision they can work on a plan of how to bring the crossing designer on the market.

AIP also need to discuss with their software engineers in what kind of environment to build the crossing designer. The concept is designed for a web-based environment, although within AIP they haven't decide jet if they would like this type of software. Also they need to take a closer look on how they integrate the database of E-Brida within the crossing designer. The software engineers need to make a model of how they are going to build the functionality of the crossing designer.

The current concept doesn't have a user interface that is thought about in context of design. They should do research to the style of interfaces of products that users do and make a design for the style of the crossing designer.

When they have done research on these topics they can make a prototype of the crossing designer and use this to do tests. They should do some extra user test to see if the product is in line with the user needs, but also to detect technical mistakes in the product.

When all this is done the crossing designer can be brought on the market and could support breeders during the making of crosses. Still then the crossing designer needs to be maintained, but also developed further. The test results showed that users would like to have a more predictive support from the crossing designer as a control. Early research showed that it was still hard to realise that currently, but as technology is changing it might be possible later. Also after bringing the product on the market user may change from needs and the crossing designer should be adapted to that.

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Appendix

Appendix I: Assignment

Assignment

Agri Information Partners is creating a separate function within E-Brida to make crossing schemes, the crossing-designer. The crossing designer is an improved version of the current opportunities in E-Brida to make crossing schemes. In demos and other partnership relative activities came forward that E-Brida doesn't support the breeder enough to create crossing schemes. E-Brida has a lot of information but it isn't visual brought clear to the users. In developing the crossing designer Agri Information Partners is interested in the needs of the users during use of E-Brida as support for making crossing schemes. This information they can use in the development of the crossing designer.

Agri Information Partners is especially looking for visual adaption to the consumer needs, they have already knowledge about the functions (input and output the crossing designer need and will give) but they want to make it visual useable for the breeders.

Goal

Agri Information Partners is interested in concept user interfaces for their crossing designer as part of E-Brida. There will be looked for visual improvement of the crossing designer, to make it more usable for the breeders. There will be done first research to the current problems users have with the crossing function of E-Brida, to find out on which aspects need improved visualization, and what problems improvement of visualization should solve. The focus of the assignment will be on the analysis and concept phase of the design process.

Research Question

Main research question: How could visual adaption to consumers need make the new crossing-designer more user-friendly?

Sub research questions:

- Analyses:
  - Which comparable products are on the market?
    - What do these products support?
    - How do they look like?
    - How do users think about these products?
    - How do they use these products?
  - Who are the users?
    - Which role does the user have?
    - Do they use other product?
    - What other software do they use?
    - What is the user profile?
    - What are their wishes?
    - How do they make crossing schemes?
    - In which step do they need support?
  - What is the usability of E-Brida
    - How do users use E-Brida?
    - How do they think about usability of E-Brida?
    - What is the usability of other software they use?
    - What are latent needs?

How can the crossing designer be in line with the rest of E-Brida?

Ideas:

What are the problems for the crossing designer?

What are the solutions?

Which solution can be combined to make crossing designer?

Concepts:

Methods

The methods that will be used to answer the research questions are different for each sub-research question. As for the concept not all research questions are fully defined during the project their need to be feedback moments to fully define. In the planning of the project this should be taken into account. The methods that are used are *(Eger, 2008)*;

- Desk research

During desk research information from literature and the Internet will be collected. This will give an overview of already existing information about the assignment.

- Interviews

During interviews people who have interest in or knowledge about the project will be asked to share their information. This will give more insight information about the subject. Within this project it will be users and developer of E-Brida and crossing schemes. During interviews fact can be discussed but also opinions.

- Tutorial Discussion

This is comparable to the interview, although these are discussion with the tutors who are more involved with the assignment. The discussion will be more open, and there will be more input/advice from the tutor.

- Usability experiences

A lot of products will be compared with E-Brida, a good way to evaluate those products is by using them. By using the products, experiences and evaluation can be done by myself.

- Test Trials

During test trials, users will be asked to use E-Brida or other software. Their usage behavior will be evaluated. During trials specific tasks can be asked to do, to be evaluated.

- Scenario Writing

Scenarios are written based on received information from users, and their usage behavior. The scenarios will be analyzed which would give new information and may reveal latent needs.

- Comparison

During the comparison, things will be compared to each other. In this assignment, mostly different software will be compared to each other or to E-Brida. Also different type of users will be compared to each other.

- Morphologic Scheme

A morphologic scheme is a method where solutions and techniques for smaller problems are set out against each other, to make new combinations, which will lead to new product ideas.

- Brainstorm

A brainstorm is a session wherein a group of people, with different expertise will discuss the problem with each other and will come up with ideas.

Appendix II

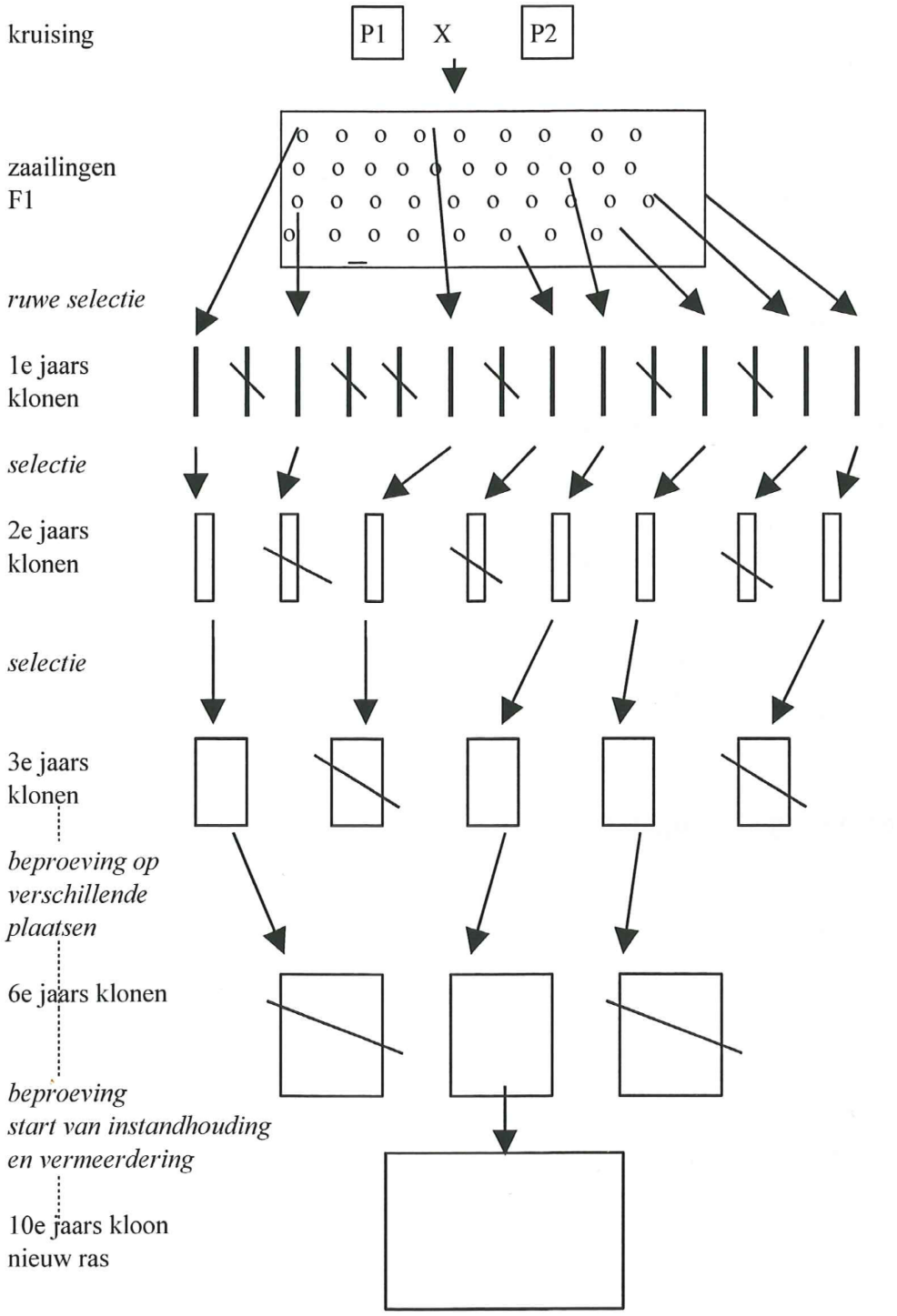

Figure 1 Breeding scheme of vegetative reproduction plants (Breedwise, 2014)

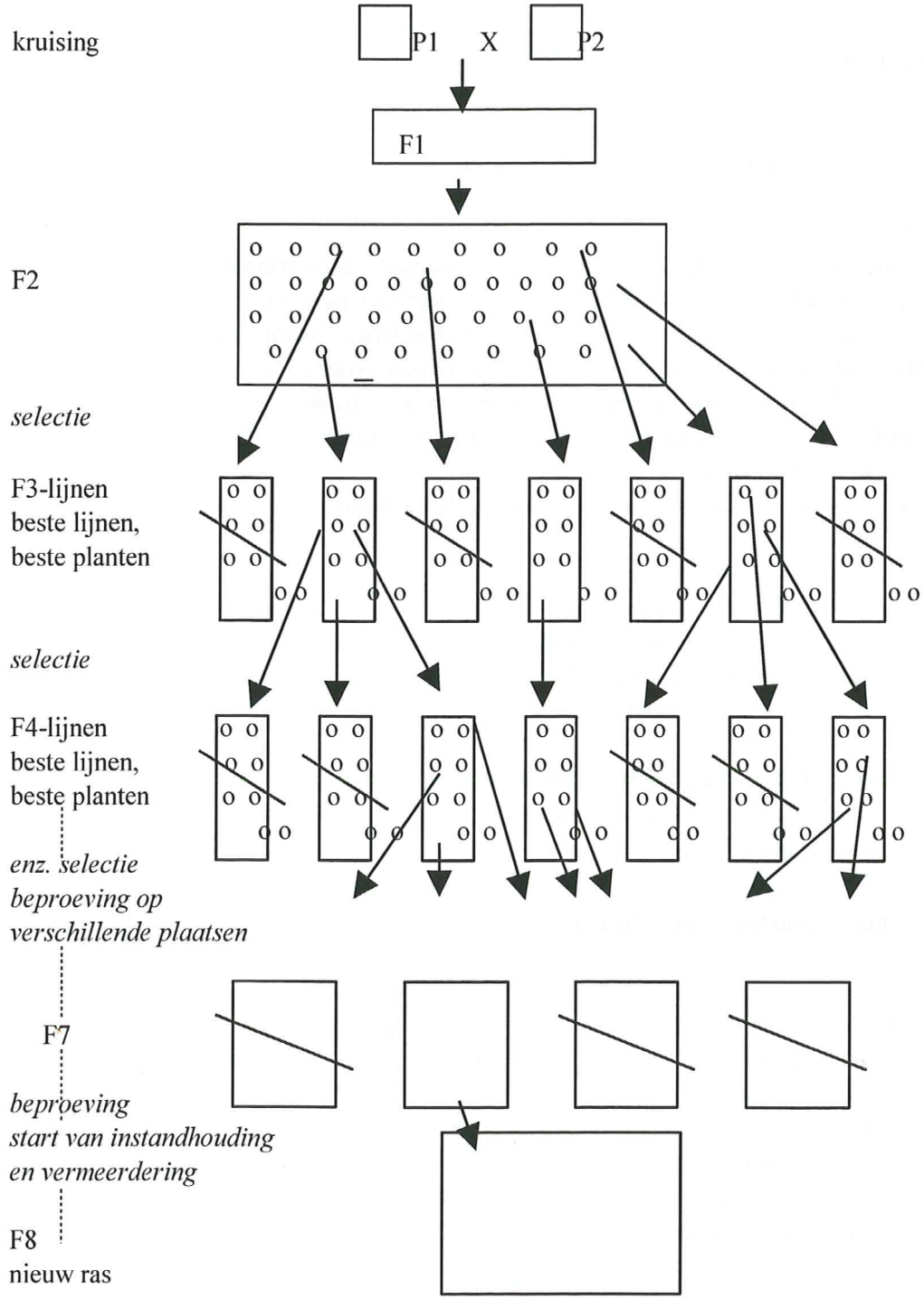

Figure 2 Breeding scheme of self-pollination plants (Breedwise, 2014)

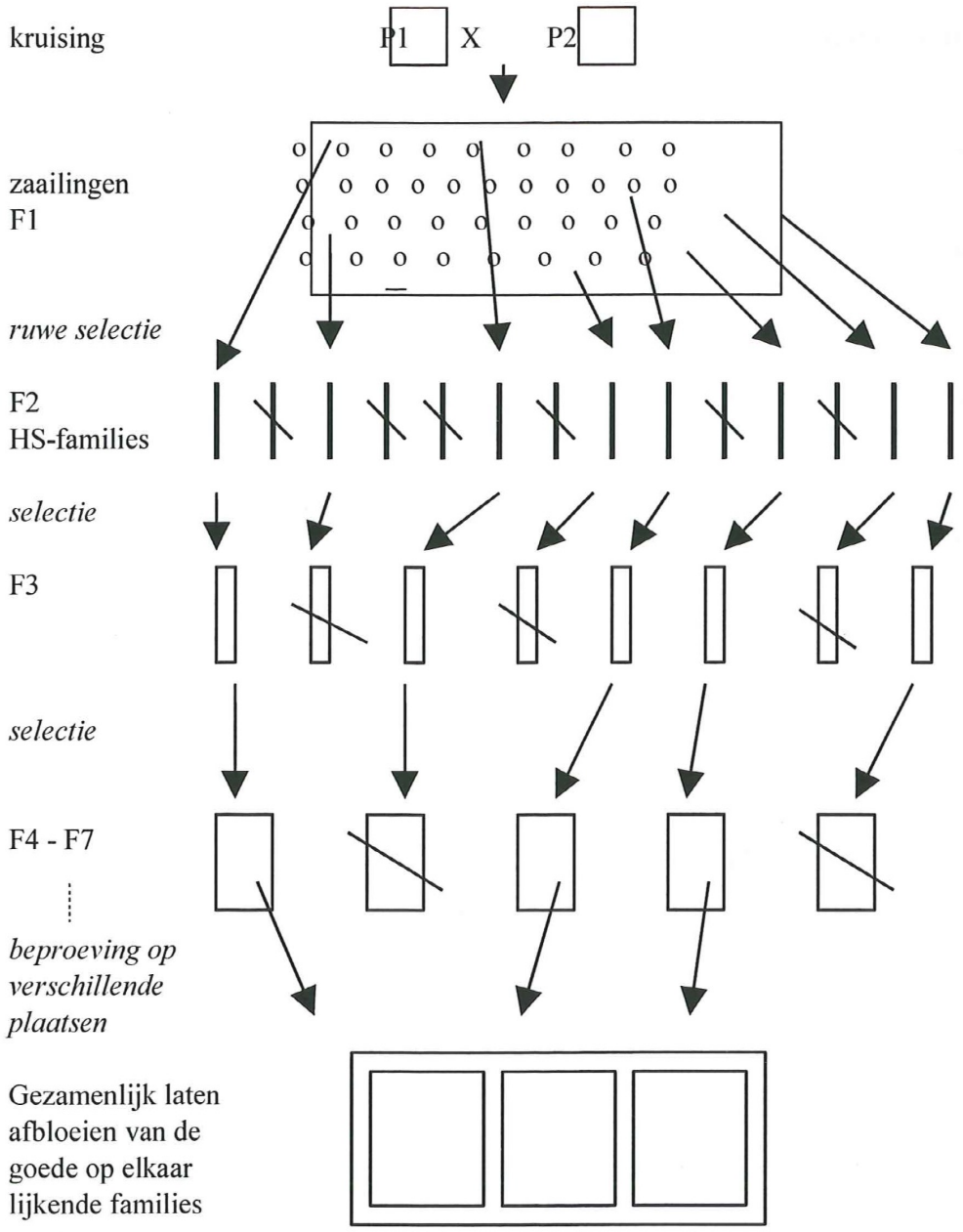

Figure 3 Breeding scheme of cross-pollination plants (Breedwise, 2014)

Appendix III: Interviews

Interview Moerheim

Rose company, just started with breeding of roses in the Netherlands yet, before only selection of roses. Moerheim doesn't use E-Brida, but are interested because for breeding it is important to have data about the plants. Breeders need information from selectors. Within Moerheim everyone use his own database, or method to store the data. They want to make data more useable for everyone and are therefore looking for a system where everyone can store the data in. The breeding activities have just been started at Moerheim (Netherlands) and therefore the breeders has started to make a database in Excel.

Demo E-Brida by Berno van der Geest

During the Demo there is 1 breeder (the only one within Moerheim for Netherlands) and 3 selectors. The breeder has the most interest in E-Brida, because then data are stored and she can use them for making the breeding programmes. That E-Brida was more than data storage (it has a breeding programme behind it) surprised them. E-Brida can calculate average scores for example.

Demo E-Brida (tablet) by Berno van der Geest

Tablets have been used in the greenhouse before, this wasn't successful because the screens were not readable within the light. Therefore they went back scoring on paper.

Interview Eveline Spaans

She has studied plant breeding at Wageningen University. She works at Moerheim as a breeder in cutflower roses. She is the person who starts breeding activities for Moerheim in the Netherlands. Currently she used Excel to store data and support the creation of crossing schemes.

Interview Wageningen University

Wageningen University is one of the top universities in the world with a plant-breeding department. At Wageningen University there are some sub departments that make use of E-brida during there research. The activities at Wageningen University are research activities to gain knowledge, while for breeding companies it is research to make money. That makes Wageningen University a slightly different user of E-Brida as other companies.

Interview Johan Bucher

Johan Bucher is a research assistant at the breeding department of Brasica. There they make use of E-Brida to report plant material data. Within his job he has two main type of cross goals; searching for segregation within a F1 to determine genes and the making of double haploids. Double haploids differ from diploids because they are made from one single haploid cell, which is doubled through chemical means. The advantages of double haploids are that it is possible to get identical haploid offspring. Therefore a cultivar can become heterogenic and with evaluating a cultivar the genetic influence of the phenotype can be neglected.

In the database there are not a lot of plants therefore there is not a big range of choice when they make crosses., besides that they make sometimes a lot of crosses just to see what happen and find new information about plants. This is a difference with companies which have a goal with creating new cultivars. Therefore E-Brida isn't used to make crosses, they use E-Brida to put in the results of crosses and get information about the plant. When they make crosses they first make them n Excel and import them in E-Brida, because in Excel they can make multiple crosses while in E-brida each cross has to be made separate. For the scoring they do use E-Brida field, but they also print scoring forms that they fill in and which are typed in E-Brida later by students. The typing in of the scores takes a lot of time and therefore they let students do it, but it is hard to explain the students how to work with E-Brida. It is quite complicated and to use E-Brida you should know how the whole software works. For us it would be nice if the tasks would be more separate form each other and that we can let people just work with specific functions of E-Brida.

Interview Kieft Seeds

Kieft seeds is part of Panamerican seeds and is a breeding company of flower plants. They do have E-Brida but most people don't use it, or make use of the advantages of E-Brida. The American part of the company uses the software Handybase. Besides E-Brida most breeders also use Excel to exchange data between each other about the plant material. At Kieft seeds all breeders have there own crops. They do discuss with each other but everyone works on his own crops. They work within a crop with groups of plants and not with single plants, in E-Brida the group of plants are the pedigree items, thus the genetic material. With the making of the crosses they use the groups and not the single plants. So when they make a cross they just place several plants together that are all crossed with each other. A plant is therefore used for different crosses and that's hard to manage in the current E-Brida. The crossing designer seems interesting for Kieft to help planning the crosses, but it should not take over the breeders work. It has to be a support tool and the breeder has to make the decisions.

Interview Han Sasbrink

The breeding process differs for each crop and is different for every breeder. The numbering system is very important. Seedlings get a number, and in this number information is already told. The numbering system is different between breeders and need uniformity to work all within the same system. It is already visible that crosses are made but that the people in the greenhouse don't get the cross and make a wrong cross. This will cause problems in the numbering but also in the results.

They have two cycles a year with most plants, and they have two codes a year. With the making of crosses the breeder first look, which plant material, is available. In the field the breeder already has in mind which plant material is interesting and when the material is available the breeder makes the cross while being in the field. These are mostly the developmental crosses, from the crosses the interested plants will be turned into lines. For the making of the lines a planning of crosses is made. Lot of the crops have specific moments that they can be crossed and therefor it is important that when that moment is there they are crossed with also flowering plants. There are always possibilities and as breeder you have in mind what your goal is and which plants you could cross the best. E-Brida is used in this case afterwards to report the crosses, mostly the data are imported from Excel to E-Brida. This is the reason why a lot of the data of Han are still not in E-Brida because he has no time to fill them in E-Brida. On the moment he was 3 years behind.

Interview Valentin

Uses E-Brida during the breeding process, he has a field computer with E-Brida on it. He works the same as Han, go to the field and watch which plants are flowering and make crosses. He uses E-Brida to get information about the plant he wants to cross, to be sure he makes promising crosses. It isn't possible to remember everything of every plant. Hard is that E-Brida isn't designed for the field computer thus sometimes difficulties with reading or fitting all the information in the screen. He also makes export lists from E-brida to Excel and saves the plant material under the different goals where he is working with, so he knows which plants are used in which goal. In the field he uses these list to check whether crosses are made already before or if plant material could be better used for crosses with another plant. Use the filter options to search for material.

Interview Corn Bak

Corn Bak is a breeding company with the main plant Bromelia, they also have breeding activities with other ornamental plants. The company uses E-Brida, but is still in the begin stages with getting all the existing data in the system.

Interview with Rudy Steentjes

When crosses are made there are 3 main types of information needed: which plants are available, which crosses are possible and which crosses are already made. The breeder will go to the greenhouse and has this moveable book shell with all the information of all the plants in it. When a plant is flowering the breeder has to take this opportunity to cross with another plant that is flowering (a lot of plants do flower only once a year). With the books the breeder has the information of which crosses have been done. All plant material is in the greenhouse and the breeder will just go to the greenhouse to make the crosses. In meetings with all the breeders there will be discussed goals what to achieve with the breeding and the breeder has this in mind. The problem is that it sometimes faiths away.

With the goal in mind there are first made developmental crosses, when these results are in line with the goal there will be looked more to the details of the plant. The breeder watches also if what he is expecting will be the result, his expectations come forward of the pedigree tree of the plant.

The crossing designer would be interesting to have more control about the crosses, it would be nice if it is part of E-Brida because a separate program makes it more work. The information in E-Brida is also used to make crosses and the crosses made in the crossing designer are the new pedigree items in E-Brida. Currently in E-Brida it is hard to remove pedigree items, but with the crossing designer you are planning crosses and only the crosses that are made should become pedigree items and not all. A lot of crosses are made but not all the seeds are grown, and when they are grown not all plants are saved. These plants stay in the collection but aren't described as individuals but as a group and therefore there is not the information available about these plants to use in the crossing designer. To let the crossing designer work optimal not only selected plants need to be reported as individual in E-Brida but also the other plants. These plants stay in the collection and could be used within other goals. The scores of the plants are imported in deciding whether to use it in a cross or not and should therefore be all reported.

Plant 1 is mostly already available the crossing designer should help in finding plant 2, it could bring up potential plants to achieve a goal. The crosses can be made already at the desk. When the plant is flowering the breeder already knows which crosses he had planned. It would be nice if the system shows only the crosses that are possible thus of plants that are also flowering. By making the crosses already there is more direction in achieving goals.

Interview Rijk Zwaan

Rijk Zwaan is a big breeding company in the Netherlands that works international. It has breeding activities in a lot of agriculture crops. The company has its own breeding software VNG, which is a recently update of there old breeding software. The software is comparable to E-Brida and doesn't have a crossing designer.

Interview Bianca van Haperen

Does breeding activities for peppers, the crossing schemes are made 2 times a year. They work with goals, where plant material belongs. The goals are based on what they want to achieve with a plant and mostly explained with plant traits. The field lay out is based on these goals. Within the goals there are made crosses a cross group and the F1 becomes a sub group. The end goals are to create hybrids by creating a father and a mother line, but first developmental crosses are made to create a parent. Within the subgroups selection takes place for the next generation. A subgroup of the F1 will be the pedigree item.

When the crosses are made all the available material will be evaluated and will looked for interesting cross partners. During the selecting the available material is selected and the rest is thrown away and will not be worked with. There is a list of criteria for each goal of the mother and father plants. The plants have to have these criteria and there are no compromises this because there is often too much choice, and just a limit amount of space. For all the crosses there will be looked if they have been done before and there will be written for each cross why it will be done or not.

VNG has no crossing designer, to make crosses Excel is used. In Excel there is the possibility to filter the data and select multiple data. VNG is useable for small experiments but for bigger Excel is better because you don't have to make every cross separately. Disadvantages of using Excel is that not all the data are together, there are a lot of different lists and therefore you might miss interesting crosses. It is imported that data from Excel are always exported in VNG and then exported to Excel to work further with, to make sure all data are up to date.

With the crossing designer it would be nice if it could have like a to do list of all the things there is working on.

Interview Interplant

Adri van Doesum is the breeder at Interplant he does all the breeding activities by himself within Interplant. He uses E-Brida as support for his breeding activities.
Within Interplant there are two cultivars defined, wherefore separate breeding activities are done for. They have cut flower roses and garden roses. Adri makes the crossing schemes at the beginning of the year at his office.

Breeding process

1. Selection of genitors.

After summer the crossing greenhouse will be cleaned (this where the genitors are). For the next year the new genitors will be selected and grown (during the whole year genitors are selected but then they are grown). The main aspect for selection of the genitors is or the plants are making seeds.

2. Looking for crosses using the F3 filter

The breeding goals he makes during the year and are in his head. In making the crosses and filtering he tries to take as many traits/properties into account.
Within roses the breeding goals are not based on the market, this because it shift too much and breeding takes too long, but they are thinking which way will the market go to. During breeding the approach must be broad. For roses there is a stable market for the basic colours. The market of roses is determined by; consumers, traders and growers, all three with different interests.

3. Selecting crosses

When crosses are made we have to select which has to be carried out. This depends on whether crosses are already made earlier. (This is not visible in E-Brida).

E-Brida usage

Adri doesn't use all the functions within E-Brida, but a lot he does. He talked with other E-Brida users from other companies, and there he sees other usage of E-Brida. He says E-Brida has a lot but everyone has to find out for himself how to use it. When he uses E-Brida especially to support during crossing schemes making

Interview Agrico

Agrico is a potato breeding company and uses E-Brida. The breeders at Agrico have there own potato segment where they make crosses for 1 time a year and discuss them together with the other breeder before the crosses take place. Potato has 15 segments which have been subdivided as well, for some segments there is no potato export and therefore there are different cultivars so that they can grown at different location under different conditions.

Potatoes are tetraploids, which have vegetative reproduction therefore it is harder to make crosses. When 2 plants are crossed it will have an offspring of around 250 plants, and around 500 crosses are made each year. Selection is therefore very important, selecting takes place for each plant individual, the interesting plants are cloned for 4 years and after 4 years they can take part as crossing parents. At Agrico they want to make broad cultivars, which means average good in average conditions. A plant can be used as a crossing parent after 4 years therefore they have a special genitor programme where they just create genitors, which can be used as crossing parents to make a cultivar. The genitor programme is separate and doesn't use E-Brida.

When Breeders make a new cross there will be looked for like 3 until 8 specific properties as a goal for the new cross, while in total around 50 properties are taken into account. The breeder will look at his material and he wants to have information about the properties of the parents of the plant. They also want to know the properties of the plant and the amount of data. Younger plants have less data and the values are less reliable because they can be influenced too much by extreme conditions in a year. And the breeder would like to have photographs of the plant.

Interview Sjefke Allefs

Works a lot on paper and will put his data later in E-Brida. All the material is on a list and for every material there will be written down the positive and negative characteristics in 3 letter codes. For all the material the main interesting points are written down and it will group for which goals it is useable with a usability mark. While doing this plant material is also removed, within the plants selection otherwise the list of material will become bigger every year. For the plant material will be looked or they can be used as father or mother, their have to be selected multiple parents because having different parents will give more variety within the cultivars. All the information will be placed in Excel and for each group is a list of father plants and mother plants which can be crossed with the group. For each segment the fathers will be selected and for each father 4 mother plants will be searched for. When the father is elected the properties are placed next to it to sees what kind of mother plant is needed. The father and mother are placed next to each other and properties are evaluated. E-Brida is used to filter for a mother when the properties of the father are known and the breeder knows for which properties she is searching in a mother plant. The pedigree tree is important as well, because inbred isn't bad but to maintain genetic variation and create new cultivars it is important not to cross constantly in the same group of plants.

Interview Maarten Vossen

When he makes crosses he uses E-Brida directly to make the crosses, he uses Excel to make lists of the crosses because he first has to discuss the crosses with the other breeders before they can be placed in E-Brida. In E-Brida he uses the F3 Filter to search for plants that can be used as father. For each segment he creates a new F3-Filter, it would be nice if he could save his F3-Filters. From the filtered fathers the best are selected to use in crosses and then look for which segment it could be useful. Sometimes afterwards when the segment hasn't enough fathers there will be looked specific for a father for that segment. These list of fathers are placed in Excel for each segment. For each father will be looked with the F3-Filter in E-Brida for around 4 mother plants. It would be nice if E-Brida could cerate filter setting for the mother when a father is selected. The mother plants properties are compared to these of the father to see if they are good candidates. Then the crosses are discussed and imported from Excel to E-Brida. The advantage of Excel is also that you have an overview of all the planned crosses within the segment. Working with Excel and E-Brida has a bigger risk of making mistakes because data are transferred continuously. Support with making crosses woul be nice because the making of crosses is time consuming because the looking up for information and candidate plants.

Appendix IV: Protocols

Web-Based

Je bent een rozenveredelaar en gaat naar de website van de crossing designer om in te loggen. Je gaat aan een nieuw veredelingsproject werken namelijk het maken van roze met wit gestreepte rozen (pink/white striped roses, de details worden automatisch ingevuld van het project)

Aan dit project met als doel de roze met wit gestreepte rozen wil je dus eigenschappen gaan hangen. Je wilt namelijk een rode roos maken en daarvoor moet zowel de vader als moeder rood zijn, met prioriteit 1. Ook voor de intensiteit van de kleur wil je een instelling doen (overige eigenschappen vullen automatisch in). Nadat je de eigenschappen hebt gedefinieerd wil je een nieuwe activiteit toevoegen namelijk de eerste kruising voor het project (pink/white striped first cross, detail worden automatisch ingevuld)

Als je verder gaat met het selecteren van materiaal, besluit je aan een andere activiteit te gaan. Je maakt een nieuwe activiteit aan, het verder kruisen met de geselecteerde van de eerste kruissing. Voor het bijeenzoeken van het materiaal maak je eerst een filter. Je wilt graag filteren op planten die meer dan 30% rood gekleurd zijn. Je geeft deze filter de naam filter 1. Met het filter kan het plant materiaal gevonden worden. Je maakt een materiaal lijstje met ouder materiaal (naam: parental). Je gebruikt hiervoor het aangemaakte filter. Alle resultaten wil je graag toevoegen aan de materiaallijst.

Nu het materiaal geselecteerd was kan er een kruisingsschema gemaakt worden. (naam: developmental first cross). Voor zowel de vader als de moeder selecteer je het materiaal van het voorgaan gemaakte materiaallijstje. Als het kruisingsschema is gevormd wil je graag wat extra informatie weten over de eerste kruissing. Vervolgens wil je dus de kruisingen gaan selecteren die je wilt gaan uitvoeren. Je maakt een lijst aan met kruisingen die je wilt gaan uitvoeren (naam: test trial 1), hiervoor gebruik je het kruisingsschema wat je ervoor hebt gemaakt.

E-Brida

Je bent een rozenveredelaar en wilt oranje rozen kweken met resistentie C. Dit is een subdoel van het doel om resistentie C in rozen te krijgen. (de overige gegevens voor het maken van een subdoel worden automatisch ingevuld) Je gaat vervolgens de eigenschappen voor het doel definiren, voor de kleur kies je oranje (overige eigenschappen vullen automatisch in). Voor oranje wil je graag de overervingsregels laten gelden en het een prioriteit 3 geven. Voor de intensiteit van de kleur wil je 60% invullen. (overige eigenschappen worden automatisch ingevuld)

Binnen het doel wil je aan een nieuwe activiteit beginnen, namelijk ontwikkeling kruisingen (developmental crosses orange 2014). Om het materiaal te kunnen selecteren wil je een filter gebruikt die de eigenschappen die je bij je doel hebt ingesteld gebruikt (conform properties). Toch controleer je of deze filter precies is wat je zoekt en als het zo is gebruik je deze filter om de vaderplanten en moederplant te kunnen gaan vinden. Eerst ga je een moederplant zoeken en selecteren (63-397-21). Nadat je deze moederplant hebt gevonden ga je hier een specifieke vaderplant voor zoeken en selecteren (78-673-09).

Het materiaal wat je hebt geselecteerd wil je samenvoegen in een lijstje genaamd vaders 1. Het materiaal wil je met elkaar vergelijken waarbij je de plant 78-673-09 vooraan wilt hebben.

Met het geselecteerde materiaal wil je dus een nieuw kruisingsschema maken (genaamd orange 2012-II), waarbij je dus ontwikkeling kruisingen gaat maken. Je kiest voor de vader het materiaal lijstje vaders 1 en voor de moeders het materiaallijstje 2012. De planten worden door de crossingdesigner tegen elkaar uitgezet in een kruisingsschema. Bij de kruising 56-034-94 x 98-034-83 wil je een notitie toevoegen en selecteren als een kruising om uit te voeren. Ook wil je graag meer informatie over de kruising zien, en om de intensiteit van de kleur te vergelijken wil je deze eigenschap graag bovenaan hebben staan (flower colour 1 dus onder %flower color 1).

Na de kruisingen te hebben geselecteerd wil je graag alle kruisingen zien die je hebt geselecteerd en dan als kruisingslijstje voor het pollination plan opslaan.

Step-by-step structure

Je bent een rozenveredelaar en wilt een kruisingsschema op gaan stellen voor de sweetheart rozen. Het doel is om rozen te verkrijgen die geen doornen meer hebben. Dit nieuwe project wordt in Wageningen uitgevoerd maar is gericht op de consument in Spanje. De belangrijke eigenschappen zijn doornen, de hoeveelheid doornen en de kwaliteit en lengte van de doornen (Thorns, #Thorns, Thorn quality en Thorn length). Voor deze eigenschappen wil je een eigen eigenschappen groepje maken genaamd doorn eigenschappen (Je selecteert eerst alleen Thorns voor de eigenschap set en daarna de andere drie eigenschappen). Daarnaast is de eigenschap resistentie B ook belangrijk om mee te nemen in dit project. Het uiteindelijk doel is geen doornen (de overige eigenschappen vullen automatisch in) en dit heeft een hoge prioriteit. Binnen dit project wil je een nieuwe activiteit aanmaken (genaamd; thornless developmental 2014). Voor deze activiteit maak je een nieuwe filter aan (genaamd; filter 2014). Hiervoor stel je in dat een plant minder dan 3 doornen moet hebben (de overige eigenschappen vullen automatisch in). Voor de resistentie A en resistentie B wil je dat de overervingsregels gelden en dat er alleen materiaal uit 2010, 2011, 2012 en 2013 wat beschikbaar is wordt gefilterd.

De vader en moeder plant wil je apart gaan selecteren, voor de moeder selecteer je plant 93-495-92 en ook 25-374-23 en 89-467-83. Voor het selecteren van de vader wil je graag dat de resistentie A zichtbaar is (Resistance A op de plek van Thorn length), en je wilt graag een vader selecteren voor moeder 93-495-92. Als vader selecteer je vervolgens 89-256-03.

Je maakt een nieuw kruisingsschema, schema 2014 waarbij je de vaders van materiaallijstje 2014 tegen de moeders van materiaallijstje 2014 tegen elkaar uitzet. De crossingdesigner maakt na het selecteren zelf het kruisingsschema. De kruising 89-256-03 x 93-495-92 wil je wat beter vergelijken door de eigenschappen naast elkaar te zetten, waarbij je graag de eigenschap resistentie A bovenaan wilt hebben. (Resistance A boven Thorn length zetten). Je besluit deze kruising te selecteren om uit te gaan voeren, en als notitie zet je erbij dat deze veelbelovend is. (note: promising). De geselecteerde kruisingen wil je graag opslaan als een lijstje voor het pollination plan (genaamd: Thornless 2014 Experiment 1).

Appendix V: Questionnaire

Naam:
Functie:
Uiteindelijke keuze:
Volgorde:

Metingen:

	Stapsgewijs	E-Brida	Web-based
Tijd			
Fouten			
Vragen			

Volgorde 1 (meest) tot en met 3 (minst)

	Stapsgewijs	E-Brida	Web-based
Duidelijk wat te doen			
Veel mogelijkheden			
Ingewikkeld			
Functioneel			
Praktisch			

Beschrijving functie structuur van de drie prototypes
Stapsgewijs:

E-Brida:

Web-based:

Beschrijving kenmerken/verschillen van de prototypes
Stapsgewijs:

E-Brida:

Web-based:

Hoeveelheid stappen die genomen moeten worden:
Stapsgewijs:

E-Brida:

Web-based:

Positieve punten:
Stapsgewijs:

E-Brida:

Web-based:

Negatieve punten:
Stapsgewijs:

E-Brida:

Web-based:

Appendix VI: Scoring results

test person	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Function	AIP	AIP	AIP	AIP	AIP	AIP	Br	Br	Br	Br	Br	Br	Br	Br	Br	Br
Choice	3	3	2	2	3	3	2	3	3	3	2	3	2	3	3	3
Order	1	1	1	2	3	2	1	1	1	1	1	3	2	2	2	3
Time (min)																
concept 1	11	14	12	11	10	12	9	11	13	10	12	10	10	9	11	10
concept 2	7	10	9	13	11	14	7	9	8	9	10	11	14	12	13	9
concept 3	6	11	7	9	12	9	7	10	6	6	9	12	9	9	7	12
Mistakes																
concept 1	3	6	8	4	6	4	6	8	6	3	10	3	6	7	6	8
concept 2	8	5	4	9	10	12	11	5	9	8	9	8	9	12	11	5
concept 3	7	7	5	7	5	5	9	7	5	6	7	10	5	6	9	9
Questions																
concept 1	5	12	8	9	6	5	7	9	9	5	10	6	7	5	7	8
concept 2	6	11	7	12	9	11	8	10	11	9	11	9	12	10	12	11
concept 3	2	6	5	7	10	8	6	7	9	9	5	10	7	6	7	8
Clear																
concept 1	3	1	2	2	1	3	2	1	2	2	1	3	1	2	2	1
concept 2	2	2	1	1	3	2	1	3	3	3	2	2	2	3	3	3
concept 3	1	3	3	3	2	1	3	2	1	1	3	1	3	1	1	2
Opportunities																
concept 1	2	2	3	3	2	3	3	3	2	3	3	3	3	2	3	1
concept 2	3	3	2	1	3	2	1	1	3	2	1	2	1	3	2	3
concept 3	1	1	1	2	1	1	2	2	1	1	2	1	2	1	1	2
Complicated																
concept 1	3	3	3	2	3	3	3	3	2	3	3	3	3	2	3	3
concept 2	2	1	2	3	1	2	2	1	1	2	1	1	2	1	1	1
concept 3	1	2	1	1	2	1	1	2	3	1	2	2	1	3	2	2
Functional																
concept 1	3	2	2	3	3	3	2	2	3	3	3	2	2	3	3	3
concept 2	2	3	1	2	1	2	1	3	2	2	1	1	3	2	1	1
concept 3	1	1	3	1	2	1	3	1	1	1	2	3	1	1	2	2

Useable

concept 1	3	1	1	3	1	2	2	3	3	2	1	2	2	3	2	2
concept 2	2	3	2	1	3	3	1	2	1	3	2	1	3	2	3	3
concept 3	1	2	3	2	2	1	3	1	2	1	3	3	1	1	1	1

Structure

concept 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
concept 2	1	0	1	1	1	0	0	1	0	0	1	1	0	0	0	1
concept 3	1	1	0	1	1	0	0	1	1	0	1	0	0	1	1	0

Amount of steps

concept 1	2	1	2	2	1	2	2	1	2	2	2	2	1	1	2	2
concept 2	1	0	1	1	1	2	1	2	0	0	0	1	2	2	0	1
concept 3	2	1	1	1	0	1	1	0	0	1	1	1	1	1	2	2

Appendix VII: Discussion results

Positive points

General

- Saving of the filter
- Visible which crosses have been made before
- Possible to show results of crosses that already have been made
- Separate goals for parental plants
- Export function to Excel or to print a report on paper.
- Make from goal automatically a filter

Concept 1

- Clear what to do in a step and what the next step is.
- Visible where in the process the user is.
- Hard to make mistakes
- Critical points in the cross making the steps are important, to make sure no mistakes are made or things will be forgotten.
- Each cross has to be judged separately, can't miss any cross

Concept 2

- Filter setting could be changed continuously
- Order of importance of each step with the tabs, only first tab is obligatory to make it work; other tabs are to specify the cross.
- Can create personal work flow
- Known working structure
- Extra evaluation of the selected crosses before sending them to the pollination plan.
- A lot of extra information in the screen
- Easy to go a step back.

Concept 3

- Screen settings could be personalised, can decide which information you would like to see in the screen.
- Can create personal work flow
- Work flow feels natural because lot of software now a days work with platforms
- Working with more breeders together in the same software programme, but uses the programme to communicate as well.

Negative points

General

- Not possible to make new properties, this information needs to be set in the note.
- No filtering within the notes.
- Comparing of crosses with the final goal which has been set
- Get feedback on the crosses from the programme with comparing to the goal.
- Show status of the made crosses
- Show status of reaching the goal
- Making a list of one parent and find matching partners and see this back in the crossing scheme, instead of making father and mother list.
- Making sub list in material lists (maybe of parents that have been matched)
- Pedigree taken into account in the filter

Concept 1

- Extra information of cross can only be seen for one cross, wants to see this for multiple crosses.
- Limited in what you can do, has to follow the structure
- Making of property sets during the selection of properties, make separate steps.
- Recover of mistakes or make small changes is hard, because you have to do all steps over.

Concept 2

- Extra information of cross can only be seen for one cross, wants to see this for multiple crosses.
- Important steps can be skipped, while the user isn't aware of it because he doesn't has to go through these steps
- Not visible where the user in the process is, is caused partly by the tab structure.
- Information in the screen is too much, would be nice if you could personalize which information you would like to see.
- Visible too which goal a activity belongs, and make it possible to exchange information between activities and goals

Concept 3

- Not all information is available on each level of the platform.
- Important steps can be skipped, while the user isn't aware of it because he doesn't has to go through these steps
- Giving information only possible through selecting values, no typing in (time consuming)
- Overview always return to main menu, not possible to switch between functions
- In crossing scheme too much information, let user be able to decide setting what to see in the crossing scheme

Comments

- The structure of concept 1 should become a wizard function, which can be turned on and of to learn how to use the product.
- Maintain the step-by-step structure for the critical point of making the cross, to make sure nothing is forgotten or mistakes are made, but for the main steps of making crosses get rid of the step by step structure, it is time consuming
- Let the breeder choose whether he would like to work with a matric or a list or both.