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MELiSSA Food Characterization: phase 1

Technical note: 98.3.1

CROP CULTIVAR STUDY AND SELECTION METHOD

TN 98.3.11: WHEAT CULTIVARS STUDY AND SELECTION METHOD

TN 98.3.12: DURUM WHEAT CULTIVARS STUDY AND SELECTION METHOD

TN 98.3.13: POTATO CULTIVAR STUDY AND SELECTION METHOD

TN 98.3.14: SOYBEAN CULTIVAR STUDY AND SELECTION METHOD

prepared by/*préparé par*	Laury Chaerle, Katrien Molders
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BLSS: Bioregenerative Life Support System

Reference documents

TN 98.1.1 Elaboration of system requirements for a Food production and Preparation system (FPPS), MELISSA FOOD CHARACTERIZATION: PHASE 1

1 Introduction

The aim of this technical note is first to gather cultivar information on the 4 crops selected for the FC project experimental work. Next, with the aim to rank the described cultivars, a selection approach and method is documented, which is geared towards obtaining maximal information regarding cultivar performance in closed environment hydroponic culture bench tests. The requirements for plant growth under controlled, sealed conditions, with as a final goal to provide life support resources on long-term surface-based space missions, were taken into account, and translated into selection criteria according to current knowledge. The available data on crop performance, to be used for ranking cultivar performance according to the proposed criteria, is now largely limited to data from field-grown crops. Relative performance in field conditions cannot be assumed to be indicative of performance in hydroponic culture, therefore the first listing of suggested crop cultivars for the bench tests should be considered as preliminary. Once data from hydroponic comparative tests becomes available, it will become possible to carry out a mathematical ranking using .values for parameters associated with the identified selection criteria important for closed environment food production. For each crop a uniform table is provided with this requirement and criteria listing, and an assessment of the importance of the criteria for each crop, amended by extra parameters where relevant.
This document thus reviews crop cultivar characteristics, identifies critical points and describes the selection method for future usage. For each crop, 4 cultivars are listed for use in the bench tests, based either on data available on hydroponic culture, or on relative field performance data, combined with a maximization of diversity in key parameters, specific to the development of each crop.

2 Bread Wheat (UBern)

2.1 Introduction

The literature review of bread wheat cultivars was made. A list of selection criteria was established following the proposal. Relevant criteria for the first phase of the Food Characterization project were selected for the final selection of the cultivars. A list of the different bread wheat cultivars (winter and spring wheat) with their characteristics was established with the aim to do the cultivar selection. This list of characteristics was established following the information on winter and spring bread wheat collected in the document "Liste recommandée des variétés de céréales pour la récolte 2009" (http://swissgranum.ch/pdf/LR2009_Cereale_F.pdf) published by the research station Agroscope Changins-Wädenswil ACW (www.acw.admin.ch), the research station Agroscope Reckenholz-Tänikon ART (www.art.admin.ch) and swiss granum (www.swissgranum.ch). A search for information about the main companies and the most commercialized cultivars was made.

For the timely start of the bench tests it was impossible to consider any winter wheat species, since additional research is needed to characterize the cold treatment needed to allow the plant to flower. Winter wheat represents the largest part of the available cultivars; hence the selection was limited to a number of spring wheat cultivars, representative for the currently available high-yield cultivars bred for modern agriculture, and whose cultivation area is not necessary limited to Switzerland (see 2.1.2). Dwarf spring wheat cultivars which could be of particular interest to this study were not readily available. The preliminary selection was thus based on choosing the 4 cultivars with the best characteristics as reported for field growth, with particular emphasis on crop height. The proposed short list of 4 cultivars will be used in the bench-tests for a preliminary characterization of performance, according to the extended list of criteria (see 1.1.1).

A preliminary experiment was run in hydroponic pot culture to obtain a realistic value of crop height and generation (crop cycle) time, in the same controlled environment room that will be used for the planned bench tests which will be used to evaluate the cultivars according to the selection criteria.

2.2 Full selection process

2.2.1 Criteria selection for the Food Characterization phase 1 and 2

Broad selection criteria for consideration in future selection exercises are detailed in Tab. 1. Clearly data for a a lot of the parameters linked to these criteria are not available in literature or from breeders, and hence cannot be included in the preliminary selection approach intended to narrow the choice per crop to 4 cultivars. However these criteria and selected parameters will be used in the assessment of the 4 cultivar comparison (bench test evaluation).

Tab. 1 Crop cultivar selection criteria – italics: in this phase of low priority

Requirement s	**Criteria**	**Major parameter(s)**	**Associated parameter**
Physical - system volume Operational - automation	Crop cultivar stature	Growth space	Handling (harvest)
Performance – food quantity	Crop cultivar target environment	Growth efficiency	Available light levels (energy); CO2 level - supplementation
Performance – temporal food availability		Growth period length	Crop senescence
Operational – BLSS interface	Cultivar harvest index	Waste production	Waste degradability
Functional – produce crops		Influence of plant growth system	
Performance – food quality	Cultivar nutritional composition	Absence of anti-nutritional compounds	Pro-nutritional compounds
Performance – food quality	Cultivar edible part composition	Processability	Possible conflict with levels of pro-nutritionals
Performance – food quality		Storage stability	Storage time
Performance – food quality		Palatability	
Performance – food quantity Interface – BLSS	Water use efficiency	Maximum water use Increases growth efficiency	High water turnover rate – regeneration rate
Interface – BLSS		atmosphere regeneration capacity	O2 production
Performance – food quantity	Volatile organic compound (VOC) production	Ethylene	Growth inhibition
Performance – food quantity	Root exudate production	Allelochemical inhibiting plant growth	Interspecies compatibility
Human factor – crew time Operational - automation	Labour requirement	Unlikely to find large difference for this parameter	Monitoring sowing transplanting
Operational – degraded mode	Resistance to stress	Abiotic stress	Recovery from hardware malfunction
Performance – quantity / availability		Biotic stress	System cleanness maintenance
Functional – crop production	Pollination needs	Self-pollinating cultivar reqs	
Human factor – crew time Physical – system	Propagation	Seed to seed or vegetative	Seed handling/storage
Operational	*Behaviour in extraterrestrial conditions*	*Reduced gravity / reduced pressure*	*Radiation influence*

2.2.1.1 Additional crop-specific selection criteria

These criteria can only be used to select among cultivars using data from crops grown in controlled environment chambers, which is not available at this stage of the research..

- Resources, where and if it is possible to obtain the cultivars, “availability”
- Suitable for hydroponic culture (data not available)
- Shoot length (shorter plants are desirable for culture in growth chamber)
- Duration of the generation (should be short, preliminary tests were made indicating a period of 110 to 130 days from the seeds to the kernels, see part 5)
- Precocity of ear emergence
- High yield / Edible versus non-edible parts
- Stress tolerance
- Disease resistance
- Resistance to lodging
- Protein content (total proteins)
- Gluten content
- Baking quality
- Vernalization (exposure to low temperatures to cause induction of flowering of winter wheat)
- Transpiration rate
- Photosynthetic rate
- Water use
- Oxygen production
- Senescence and maturation properties
- Macro and micro-nutrient accumulation and redistribution

2.2.2 Selection criteria for the first phase of the food Characterization project

Selection criteria for the bench-test selection trial (parameters for which information will be available):

- Availability of the cultivar
- Shoot length
- Generation time
- Precocity of ear emergence
- High yield
- Disease resistance
- Resistance to lodging
- Gluten content
- Protein content
- Baking quality
- Vernalization

2.3 List of cultivars with their characteristics

This list of characteristics was established following the information found in the document "Liste recommandée des variétés de céréales pour la récolte 2009" (http://swissgranum.ch/pdf/LR2009_Cereale_F.pdf). This list is helping the Swiss farmer to choose the best bread wheat to be cultivated on their field. The selection of these cultivars of wheat is made every year after the grains passed several tests. The main objective of Agroscope is to select winter and spring wheat with high baking quality, good resistance to diseases and high yield (Fossati and Brabant, 2003). The information in this list is qualitative. Some quantitative data about yield, precocity of ear emergence, height of the plants, content of proteins, weight per 100 liters of grains and weight of 1000 grains were added in the list. This information was found in the report "Blé d'automne Winterweizen 2006" (http://www.db-acw.admin.ch/pubs/ch_cha_06_bos_rap_ble_automne_resultats_f.pdf) for the winter wheat and the report "Blé de printemps Sommerweizen 2007" (http://www.db-acw.admin.ch/pubs/ch_cha_08_pub_ble_printemps_resultats_f.pdf) for the spring wheat published by the research station Agroscope Changins-Wädenswil ACW and the research station Agroscope Reckenholz-Tänikon ART. The small difference in the qualitative and quantitative data are due to the fact that quantitative data were for the year 2006 (winter wheat) and 2007 (spring wheat), while the qualitative data were from the year 2008. Differences may occur in the growth of the plants for the different year of cultivation.

2.3.1 Spring wheat

Spring wheat is a predominantly cultivated cultivar throughout the world. But in Switzerland, spring wheat plays a minor role as compared to the winter wheat (Brabant et al, 2006). Nevertheless, the varieties of spring wheat selected in Switzerland are of high baking quality. For the year 2009, there are five recommended cultivars of spring wheat. All these spring wheat are of very good quality. All of them are classified in "top" and "first" quality. The most important criteria of selection are the baking quality, the resistance to diseases and the yield. The variety Greina, precocious and productive for her class of quality "first", has the particularity to be resistant to cold and can be sown also in autumn (Brabant et al, 2006). The variety Greina is also cultivated in other countries such as Spain, Argentina, Portugal and Uruguay (Brabant et al, 2006). The variety Fiorina is also very promising because it combines a high baking quality, a good yield and a very good disease resistance. Moreover, this variety may also be sown in autumn and shows a good resistance to the cold (Brabant et al, 2006). The varieties Aletsch and Carasso have a higher resistance to diseases than Greina and a very good yield. Carasso may also be sown in autumn (Brabant et al, 2006). The variety CH Rubli is a new very promising variety which has a very good potential of yield and resistance to diseases.

Fiorina, Aletsch, Greina and CH Rubli will be of high interest due to the fact they are precocious or mid-precocious for the ear emergence and they are of middle or middle to short height.

The University of Bern already used grains of Fiorina, Greina and CH Rubli. The three cultivars of spring wheat showed a higher germination potential than winter wheat Arina (Fig.

1). The grains of Aletsch, recently ordered, arrived on the first of July at UBern. A new test of germination was made to compare the four varieties of spring wheat with the winter wheat variety. After 3 days of germination, all the spring wheat varieties showed a 100 % level of germination, while the level of germination for Arina was 96.6 %. But the developmental stage after 5 days of germination differed for the various varieties (see Tab. 2).

Tab. 2 Spring wheat varieties

Variety		Fiorina *	Carasso*	Aletsch	Greina*	CH Rubli
Year of inscription		2001	2005	2003	1994	2008
Quality class		Top	Top	1	1	1
Yield		good	middle to good	middle	middle to weak	good
in q/ha		44.5	40.9	38.2	37.1	46.4
Precocity of ear emergence		mid-precocious	late	mid-precocious	precocious	precocious
± days comparing to standard variety		0.5	3.3	1.6	− 5.7	− 2.3
Height of the plants		middle to short	middle	middle	middle to short	middle
in cm		81.9	90.6	87.5	70.8	86.0
Resistance to	**lodging**	good	good	good	good	good
	powdery mildew	good	very good	good	middle	good
	yellow rust of wheat	very good	good	middle	middle	good
	brown rust of wheat	middle	middle	middle	good	middle
	Septoria nodorum on the leaves	middle	middle to good	middle	middle to weak	middle to good
	Septoria nodorum on the ear	middle	middle	middle	middle to weak	middle
	Septoria tritici on the leaves	middle	middle	middle	middle	middle
	fusariose on the ear	middle	middle	middle to weak	middle to weak	middle to weak
	pre-harvest sprouting	middle to good	middle to good	middle to good	middle to good	middle to good
Content of proteins		good	good	good	middle to good	good
in %		15.3	15.6	15.8	15.4	15.7
Quantity of gluten		middle to good	middle to good	middle to good	good	middle to good
Weight for 100 liters of grains		middle	good	very good	very good	very good
in kg		76.2	78.7	79.4	77.2	79.9
Weight of 1000 grains		middle	middle	small	small	small
in g		37.7	38.8	33.1	31.7	33

* can be sown in autumn

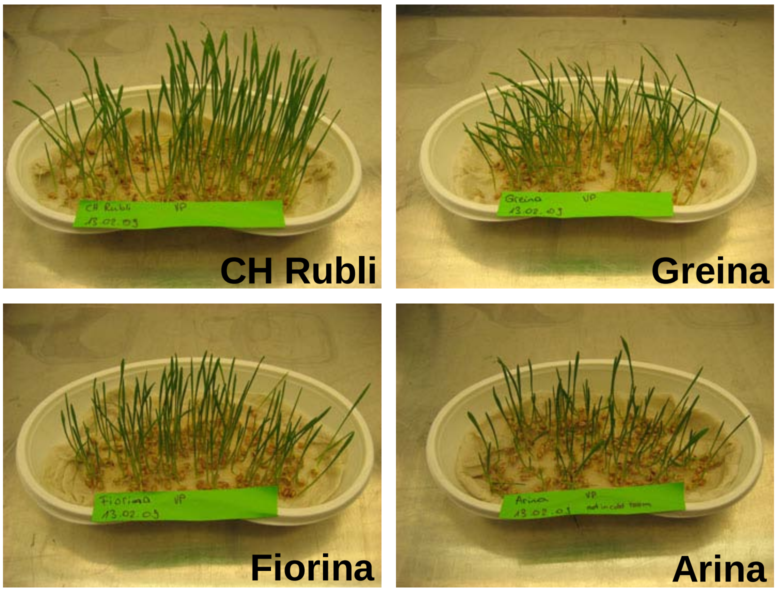

Fig. 1 Germination of spring wheat CH Rubli, Greina, Fiorina and winter wheat Arina

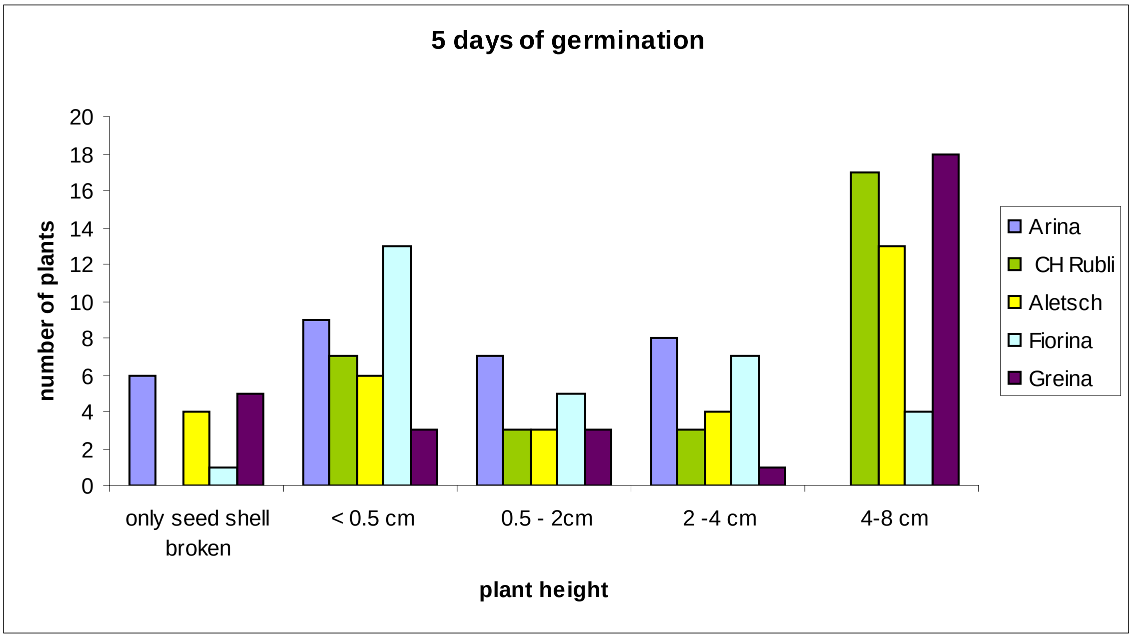

Fig. 2 Developmental stage of wheat 5 days after germination

It is interesting to know that three varieties of spring wheat (Fiorina, Greina and Carasso) may also be sown in autumn. These varieties are resistant to cold periods (and lower light levels, as typical for the cold season in temperate regions), which might occur (typically during a narrower timeframe as compared to seasonal cold periods) during a closed plant growth system temporary breakdown.

2.3.2 Winter wheat

There are 17 recommended cultivars of winter wheat in Switzerland classified from “top” to “third” quality. Arina is the most cultivated variety in Switzerland. This variety combines a good baking quality, high resistance to pathogens (particularly to Septoria and Fusarium) and a good yield. Siala has similar qualities as Arina with the advantage of a higher precociousness and a smaller height.

Arina has been grown with success (at the vegetative stage) since several years at the University of Bern. However, for the Food Characterization project, Arina is not the best choice due to its very long stalks (tall plant stature) and the mid-late emergence of the ear. Siala which is of top quality, very precocious for the ear emergence and with very short stalks (small plant stature) is a better candidate. But all the winter wheat varieties need a vernalization period (see chapter 2.4) which is a disadvantage since this causes the growth period to be longer for the winter wheat than for the spring wheat.

Tab. 3 Winter wheat varieties

Variety		Runal	Segor	Siala	Titlis	Arina	Arolla	Zinal
Year of inscription		1995	2002	2006	1996	1981	2003	2003
Quality class		Top	Top	Top	Top	1	1	1
Yield		middle to weak	weak	middle to good	weak	middle to weak	middle	middle to good
	in q/ha	64.4		72.9		65.7		75.6
Precocity of ear emergence		mid-precocious	mid-precocious	very precocious	mid-late	mid-late	mid-late	very precocious
	± days comparing to standard variety	0		-2.9		1.7		-3.1
Height of the plants		middle to short	middle to short	very short	middle to long	very long	short	short
	in cm	100.9		91		121.5		96.1
Resistance to	**lodging**	good	good	very good	good	middle to weak	good	middle to good
	powdery mildew	middle to good	middle to good	good	middle to good	middle to weak	middle to good	middle
	yellow rust of wheat	good	very good	very good	very good	middle to good	good	very good
	brown rust of wheat	weak	good	middle	good	weak	middle to good	middle to good
	Septoria nodorum on the leaves	middle	middle	middle	middle	middle to weak	middle to weak	middle
	Septoria nodorum on the ear	middle	middle	middle	middle	middle to good	middle to good	middle
	Septoria tritici on the leaves	middle	middle	middle	middle to good	middle	middle to good	middle
	fusariose on the ear	middle	middle to good	middle	middle to good	good	middle	middle
	pre-harvest sprouting	middle	good	middle	middle to good	middle to good	middle to good	good
Content of proteins		good	good	middle to good	good	middle to good	middle to good	middle
	in %	14.8		14.3		14		13.4
Quantity of gluten		good	good	middle to good	good	middle	middle	middle
Weight for 100 liters of grains		middle to good	middle to weak	middle to good	good	very good	good	good
	in kg	81.4		81.5		83		83
Weight of 1000 grains		middle	small	middle	big	middle	big	middle
	in g	43		43		39.3		42.3

Ludwig	Forel	Levis	Tommi	Caphorn	Galaxie	Scarletta	Rigi	Akratos	Ephoros
2004	2008	1997	2007	2006	1991	2007	2004	2006	2006
1	1	2	2	2	2	2	2	3	3
good	middle to good 74.6	middle to good 67.5	good	good	middle to good	middle to good	middle to good 74.2	very good	very good
mid-precocious	precocious -1.1	mid-precocious -0.4	mid-late	mid-precocious	very precocious	very precocious	mid-precocious 0	mid-precocious	mid-late
very long	middle 102.2	short 89	short	very short	very short	very short	very short 93.3	middle to long	middle
middle to good	good	good	good	very good	middle to good	good	good	middle to good	good
middle to good	good	middle to weak	middle to good	middle to good	middle to good	good	good	good	middle to good
very good	middle to good	good	very good	very good	middle	very good	very good	good	good
middle	middle	midle to good	middle	very good	weak	middle	good	middle	middle
middle	middle	middle	middle	middle	middle to weak	middle	middle	middle	middle
middle to good	middle to good	middle to weak	middle to good	middle	middle	middle to good	middle	middle	middle to good
good	middle	middle	middle	good	weak	middle	middle	middle to good	middle to good
middle	middle to good	middle to weak	middle	weak	middle	middle	middle	middle	middle
middle to good	good	middle to good	middle to good	middle to good	good	middle to good	middle to good	middle	middle
middle	middle 13.3	middle to weak 13.1	weak	weak	middle to weak	middle to weak	middle to weak 12.3	weak	weak
middle	good	middle to good	middle to weak	middle	weak	weak	weak	very weak	very weak
middle	very good 84.2	middle to good 79.9	very weak	weak	middle to weak	middle	middle to good 81.1	middle to weak	middle
big	middle 37.2	middle 42.5	middle	middle	middle	big	small 36	big	big

2.4 Vernalization

Plants respond to seasonal cues, such as temperature and day-length, to ensure that flowering coincides with favorable conditions. Prolonged exposure to low winter temperatures (vernalization) accelerates the progression from vegetative to reproductive growth in many plant species, including the temperate cereals (such as wheat and barley) and dicot species (such as Arabidopsis) (Olivier et al, 2009). In *Arabidopsis*, the vernalization response is, to a large extent, mediated by the repression of the floral repressor *FLOWERING LOCUS C* (*FLC)*, and the stable epigenetic silencing of *FLC* after cold treatments is essential for vernalization. In addition to *FLC*, other vernalization targets exist in *Arabidopsis*. In grasses, vernalization seems to be entirely independent of *FLC* (Alexandre and Hennig, 2008). In temperate cereals, the vernalization response is mediated by the stable induction of a floral promoter, *VERNALIZATION1* (*VRN1*). *VRN1* encodes a FRUITFULL-like MADS-box transcription factor required for the initiation of reproductive development at the shoot apex (Olivier et al, 2009). In some varieties of wheat and barley, *VRN1* is active without vernalization, so plants do not need to over-winter to flower. […] In wheat, an insertion in the promoter of the *FT1* gene causes increased *FT1* expression (identified genetically as dominant alleles of the *VRN3* locus. Genetic variation in *VRN1*, *VRN2* and *FLOWERING LOCUS T* (*FT1* (*VRN3*)) has been used to breed temperate cereals suitable for different climates. For example, varieties that do not require vernalization can be sown in warm climates where vernalization is unlikely to occur, and can also be sown in spring and will flower without over-wintering (Greenup et al, 2009).

Winter wheat requires an extended period of cold to become competent to flower (Winfield et al, 2009). A preliminary experiment made in the growth chamber at the University of Bern showed that Arina, a winter wheat variety, cultivated in hydroponic culture pots (see 2.5) under the same conditions as 3 varieties of spring wheat, never made inflorescences, while all spring wheat varieties did. A short period of 48 hours at 4 °C at the beginning of the germination didn't help the plants to become competent to flower. On a website describing "the life cycle of WHEAT, from seed germination to harvest ripe with special emphasis on the development of the grain after fertilization" (www.wheatbp.net), information on vernalization period was found. The seeds of Mercia, a winter wheat cultivar, were placed for sowing at 4°C for a period of 42 days, permitting the plant to become competent to flower. The extra 40 days will result in a lower ranking of the winter wheat cultivars, since the yield is not superior to the available spring wheat cultivars.

2.5 Preliminary experiment

Three cultivars of spring wheat (Greina, Fiorina and CH Rubli) and one cultivar of winter wheat (Arina) were grown in hydroponic culture pots to test the growth chamber conditions and to know how long it will take from the germination to the harvest with these conditions.

The experiment started in February. Ten weeks later, inflorescences may already be seen on Greina, Fiorina and CH Rubli cultivars. The winter wheat (Arina) doesn't produce inflorescence.

The following picture shows winter wheat (Arina 48h and Arina) and spring wheat (Fiorina, CH Rubli and Greina) grown hydroponically on 1 liter culture pot. These plants are aged 10 weeks. From left to right: Arina 48h, Arina, Fiorina, CH Rubli and Greina.

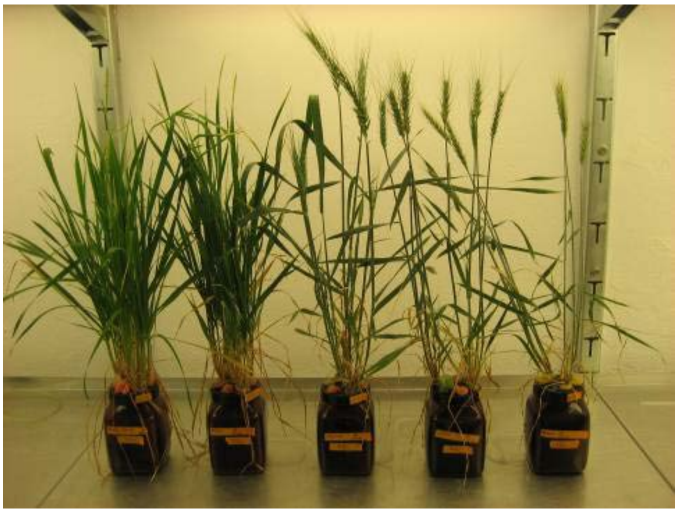

Fig. 3 Winter wheat and spring wheat grown hydroponically on 1 liter culture pot.

2.6 Literature search

Literature searches were made to identify possibly interesting bread wheat cultivars, in particular dwarf cultivars. Two interesting dwarf cultivars were found: USU-Apogee wheat and USU-Perigee wheat (www.usu.edu/cpl/research_dwarf.htm). The disadvantage of these cultivars is the current unavailability of the grains.

2.7 Cultivar short list for Food Characterization Phase 1

From the preliminary experiment it can be concluded that only the spring wheat varieties are competent for ear production in the present growth chamber conditions and with the used germination protocol. The short period of 48 hours of vernalization at 4 °C was not sufficient or not optimally timed in the wheat growth period to cause winter wheat to be competent to produce ears.

The recommended list of spring wheat cultivars shows that the spring wheat is of high quality, with a good yield and high diseases resistance. On average, the spring wheat obtained a lower yield than the winter wheat (Barbant et al, 2006); the shorter growth period of the spring wheat is however an important advantage for the Food Characterization project.

All these facts lead to the conclusion that the spring wheat varieties are the best cultivars for the first phase of Food Characterization project. Aletsch, CH Rubli, Fiorina and Greina were chosen as the 4 most suited based on the available data. In the second phase, it might be also interesting to grow winter wheat. But in this case, an adapted germination protocol including a cold period should be obtained. Siala, which is of top quality, very precocious for the ear emergence and with a very short stem (small plant size), might be a good winter wheat candidate.

Prof. Windhab (ETHZ, consultant to UBern) agrees (from a processing perspective) with the fact that spring wheat varieties will be chosen for this project.

Tab. 4 Selected spring wheat for Phase1 and proposed winter wheat

Variety	Fiorina	Aletsch	Greina	CH Rubli	Siala
	spring wheat	spring wheat	spring wheat	spring wheat	winter wheat
Quality class	Top	1	1	1	Top
Yield	good	middle	middle to weak	good	middle to good
in q/ha	44.5	38.2	37.1	46.4	72.9
Precocity of ear emergence	mid-precocious	mid-precocious	precocious	precocious	very precocious
± days comparing to standard variety	0.5	1.6	− 5.7	− 2.3	− 2.9
Height of the plants	middle to short	middle	middle to short	middle	very short
in cm	81.9	87.5	70.8	86.0	91
Resistance to lodging	good	good	good	good	very good
Content of proteins	good	good	middle to good	good	middle to good
in %	15.3	15.8	15.4	15.7	14.3
Quantity of gluten	middle to good	middle to good	good	middle to good	middle to good

In Tab. 4, the qualitative data (good, middle, precocious…) are given related to a standard spring wheat variety for the spring wheat and a standard winter wheat variety for the winter wheat.

2.8 Conclusions

The selected spring wheat cultivars seem at this stage to be the best candidates for the Food Characterization phase 1 project. They are of high quality and have the advantage to flower without the need for a vernalization period. Spring wheat varieties hence have a short life cycle. These parameters are very important with respect to the goals of this project. Even if a vernalization period will be possible in the protocol for growing plants, it will complicate and prolong the growth of the wheat.

2.9 Companies selling seeds in Switzerland

1) Eric Schweizer Ag, Postfach 150, CH-3602 Thum, www.ericschweizer.ch
2) HO Semences – Otto Hauenstein, www.hauenstein.ch
3) Fenaco - Semences UFA, www.semencesufa.ch/fra/

2.10 References

Alexandre CM and Hennig L. FLC or not FLC: the other side of vernalization. Journal of Experimental Botany 2008, 59: 1127–1135

Brabant C, Fossati D, Kleijer G. La sélection du blé de printemps en Suisse. Revue Suisse Agric 2006, 38: 73-80.

Fossati D and Brabant C. La selection du blé en Suisse. Le programme des stations fédérales. Revue Suisse Agric 2003, 35: 169-180.

Greenup A, Peacock WJ, Dennis ES, Trevaskis B. The molecular biology of seasonal flowering-responses in Arabidopsis and the cereals. Annals of Botany 2009, 103: 1165–1172

Olivier SN, Finnegan EJ, Dennis ES, Peacock WJ, Trevaskis B. Vernalization-induced flowering in cereals is associated with changes in the histone methylation at the VERNALIZATION1 gene. PNAS 2009, 106: 8386-8391

Winfield MO, Lu C, Wilson ID, Coghill JA, Edwards KJ. Cold- and light-induced changes in the transcriptome of wheat leading to phase transition from vegetative to reproductive growth. BMC Plant Biology 2009, 9: 1-14

3 Durum Wheat (UGuelph)

3.1 Introduction

Durum wheat (*Triticum turgidum* var durum*)* or macaroni wheat is the only tetraploid species of wheat of commercial importance. It was developed through selective breeding of emmer wheat (*Triticum dicoccon)* strains which were originally grown in Central Europe and Near East around 7000 B.C. (Feldman, 1976). Durum is Latin for "hard", and the durum species is the hardest (highest protein content) of all wheats. Its high protein and gluten content, as well as its strength, make durum good for special uses. Durum wheat has a long history of use for traditional flat breads and specialty breads in Mediterranean countries (Quaglia, 1988), however durum wheat breeding programs select lines for quality solely on the basis of pasta-making potential, because pasta is the most important end product.
Durum wheat has been grown in Canada since the mid 1900's, but production was low until the 1960's when a stem rust epidemic on bread wheat resulted in a switch to resistant durum wheat crops. Yields have been steadily increasing due to breeding programs, and the cultivars considered in this trial were restricted to the most recently developed and commercially scaled production varieties as they provide the highest available yield, crop quality, and a relatively early maturation (Fig. 4, Fig. 5). Final cultivar selection was based on providing a range of variation in critical parameters relating to end use quality (gluten index) and plant growth habit.

Gluten strength is one of the most important quality characteristics of durum wheat and affects the cooking quality of spaghetti and reduces breakage loss of macaroni during processing and transportation. It also affects the organoleptic properties of pasta products. Gluten, a water insoluble composite of the proteins gliadin and glutenin, is isolated from starch by washing in a weak salt solution. The separated gluten is then centrifuged to force wet gluten through a specially constructed sieve under standardized conditions. The special sieve allows for the collection of both the part of the gluten that remains on the sieve and the part that passes through the sieve. The total weight of the gluten is defined as gluten quantity. The percentage of wet gluten remaining on the sieve after centrifugation is defined as the Gluten Index. If the gluten is very weak all of the gluten may pass through the sieve, the Gluten Index is 0. When nothing passes through the sieve, the Index is then 100.

In general, the higher the gluten index value, the greater the extensibility of the resulting durum flour. Extensibility is a measure of how much the gluten can be stretched before it breaks. This is important for pasta products which require manipulation so that they don't break into smaller pieces during production, especially long thin products such as spaghettini, spaghetti, linguine, angel hair etc. For selection purposes, the gluten index was separated into three categories; low (<50), medium (50-80) , and high strength (80-100). The majority of durum wheat is now bred to be of high strength as this is the most desirable characteristic for processing.

3.2 Uses

As raw threshed kernels (not milled into flour) durum wheat is often used for couscous and tabbula, and it is the base ingredient for many soups, stuffings, puddings and pastries. When ground into flour, durum wheat, by itself or blended with bread wheat flour, is used for dried long and short pasta products, fresh pasta, and bread.

Wheat

Main Characteristics of Varieties

Variety	Years Tested	Area 1 & 2	Area 3 & 4	Irrig-ation	Protein	Resistance to: Lodg-ing	Shat-tering	Sprout-ing	Stem Rust	Leaf Rust	Stripe Rust*	Loose Smut	Bunt	Leaf Spot	Fusarium Head Blight	Relative Maturity in days	Head Awned-ness	Seed Weight (mg)	Volume Weight** (Kg hL-1)	Height (cm)
Durum Wheat	Yield as % of Strongfield																	Relative to Strongfield		
Strongfield ♣	6	100	100	100	14.5	F	VG	F	VG	VG	G	P	VG	F	VP	102	Y	40.3	78.8	92
AC Avonlea ♣	6	95	96	---	-0.2	F	VG	F	VG	VG	---	P	VG	F	VP	-1	Y	+0.1	-0.9	+2
Brigade ✪	1	102	108	---	-0.9	G	VG	F	VG	VG	---	P	VG	F	P	+2	Y	+1.1	+0.3	+6
Commander ♣	4	105	95	---	-0.7	G	VG	F	VG	VG	---	P	VG	P	VP	0	Y	+1.3	-1.2	-16
Eurostar ✪	1	96	100	---	-0.2	F	VG	F	VG	VG	---	P	VG	F	P	+2	Y	+0.6	+0.8	+4
Kyle	6	89	91	---	-0.3	P	VG	F	VG	VG	G	P	VG	P	VP	+1	Y	-0.5	-0.6	12
Napoleon ♣ §	6	95	99	---	-0.5	F	VG	F	VG	VG	---	P	VG	F	VP	0	Y	+1.2	-2.1	+5
AC Navigator ♣	6	98	90	---	-0.9	G	VG	G	VG	VG	G	P	VG	VP	VP	0	Y	+0.8	-0.3	-13
CDC Verona ✪	1	99	104	---	-0.3	G	VG	F	VG	VG	---	P	VG	F	P	+2	Y	+0.1	-0.2	+1

♣ Includes direct and indirect comparisons with AC Barrie

* stripe rust data are preliminary

** multiply by 0.8 = lbs per bushel

*** VB varietal blend

Fig. 4 2009 Saskatchewan Durum Wheat varieties

CEREAL CROPS

DURUM WHEAT

New for 2009

Variety	Code	Breeder	Distributor	Seed Availability
CDC Verona	DT540	Crop Development Centre	Crop Development Centre	—
Brigade	DT773	AAFC (Swift Current)	Viterra	—
Eurostar	DT776	AAFC (Swift Current)	SeCan	—

Variety Descriptions

							Resistance to:						
Variety	Yield % of Check	Site Years Tested	Protein[1] +/- Check	Days to Maturity +/- Check	Seed Size	Height[2]	Lodging	Stem Rust	Leaf Rust	Loose Smut	Bunt	Leaf[3] Spot	Fusarium[4] Head Blight
AC Avonlea	100		0	0	L	MT	G	VG	VG	P	VG	G	VP
AC Melita	103	11	—	0	L	MT	G	VG	VG	P	VG	F	VP
AC Morse	102	60	-0.4	0	L	MT	G	VG	VG	P	VG	P	VP
Brigade	110	6	-0.6	1	L	MT	G	VG	VG	VP	VG	F	P
CDC Verona	99	6	0.3	0	L	MT	G	VG	VG	P	VG	P	P
Eurostar	101	6	0.0	0	L	MT	F	VG	VG	VP	VG	F	P
Kyle	92	29	-0.2	2	L	T	F	VG	VG	P	VG	G	VP
Napoleon	106	56	-0.2	0	L	MT	G	VG	VG	P	VG	n/a	VP
Sceptre	101	53	-0.5	0	L	MT	G	VG	VG	P	VG	P	VP
Strongfield	101	34	0.1	0	L	MT	G	VG	VG	P	VG	F	VP
CHECK CHARACTERISTICS													
AC Avonlea	54 bu/acre	84 site years	14.3% protein	101 days									

1 Protein data is from MCVET plots harvested from 2002 to 2008. Actual protein will depend on seasonal growing conditions and fertility levels.
2 T = Tall; MT = Medium Tall; M = Medium; SD = Semi-dwarf.
3 Leaf Spot rating is a combination of resistance to tan spot, spot blotch and septoria leaf disease complex.
4 Fusarium head blight (FHB) infection is highly influenced by environment and heading date. Under high levels of the disease all varieties will sustain damage.

Yield Comparisons

			2008 Yield: % of AC Avonlea					
VARIETY	2008 Average Yield	Site Years Tested	Boissevain	Melita	Neepawa	Roblin	Souris	Wawanesa
AC Avonlea	100	6	100	100	100	100	100	100
Brigade	110	6	109	100	107	113	134	104
CDC Verona	99	6	103	87	98	95	119	102
Eurostar	101	6	115	93	94	100	108	103
Strongfield	95	6	111	98	87	90	96	93
CHECK YIELD		(AC Avonlea lb/acre)	51	79	59	83	53	58
		CV %	8.1	10.1	2.9	8.0	9.2	6.8
		LSD %	—	—	5	—	17	—
		Sign Diff	No	No	Yes	No	Yes	No

Protein Comparisons

			2008 % Protein					
VARIETY	2008 Average % Protein	Site Years Tested	Boissevain	Melita	Neepawa	Roblin	Souris	Wawanesa
AC Avonlea	14.6	5	14.4	13.5	15.7	14.9	14.5	—
Brigade	14.0	5	13.9	12.4	15.4	14.5	13.6	—
CDC Verona	14.9	5	14.2	14.3	16.3	15.1	14.5	—
Eurostar	14.6	5	14.2	13.8	16.0	14.6	14.3	—
Strongfield	14.8	5	14.3	13.6	16.2	15.3	14.7	—

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Fig. 5 2009 Manitoba Durum Wheat seed varieties

3.3 Nutritional values

Values regarding nutritional content were obtained from : USDA National Nutrient Database for Standard Reference, Release 21 (2008)

Tab. 5 Nutritional values of Durum Wheat,

Nutrient	**Units**	**Value per 100 grams**	**Number of Data Points**	**Std. Error**
Proximates				
Water	g	10.94	31	0.309
Energy	kcal	339	0	0
Energy	kJ	1418	0	0
Protein	g	13.68	28	0.272
Total lipid (fat)	g	2.47	18	0.066
Ash	g	1.78	38	0.016
Carbohydrate, by difference	g	71.13	0	0
Minerals				
Calcium, Ca	mg	34	37	1.527
Iron, Fe	mg	3.52	2	0
Magnesium, Mg	mg	144	39	3.058
Phosphorus, P	mg	508	37	20.742
Potassium, K	mg	431	37	10.204
Sodium, Na	mg	2	9	0.487
Zinc, Zn	mg	4.16	37	0.177
Copper, Cu	mg	0.553	37	0.041
Manganese, Mn	mg	3.012	30	0.249
Selenium, Se	mcg	89.4	1	0
Vitamins				
Vitamin C, total ascorbic acid	mg	0.0	0	0
Thiamin	mg	0.419	30	0.013
Riboflavin	mg	0.121	30	0.003
Niacin	mg	6.738	30	0.213
Pantothenic acid	mg	0.935	0	0
Vitamin B6	mg	0.419	31	0.017
Folate, total	mcg	43	0	0
Folic acid	mcg	0	0	0
Folate, food	mcg	43	0	0
Folate, DFE	mcg_DFE	43	0	0
Vitamin B12	mcg	0.00	0	0
Vitamin A, RAE	mcg_RAE	0	0	0
Retinol	mcg	0	0	0
Vitamin A, IU	IU	0	0	0
Lipids				
Fatty acids, total saturated	g	0.454	0	0
14:0	g	0.003	29	0

16:0	g	0.422	29	0
18:0	g	0.022	29	0
Fatty acids, total monounsaturated	g	0.344	0	0
16:1 undifferentiated	g	0.009	29	0
18:1 undifferentiated	g	0.335	29	0
Fatty acids, total polyunsaturated	g	0.978	0	0
18:2 undifferentiated	g	0.930	29	0
18:3 undifferentiated	g	0.048	29	0
Cholesterol	mg	0	0	0
Amino acids				
Tryptophan	g	0.176	7	0
Threonine	g	0.366	9	0
Isoleucine	g	0.533	9	0
Leucine	g	0.934	9	0
Lysine	g	0.303	9	0
Methionine	g	0.221	8	0
Cystine	g	0.286	7	0
Phenylalanine	g	0.681	9	0
Tyrosine	g	0.357	8	0
Valine	g	0.594	9	0
Arginine	g	0.483	9	0
Histidine	g	0.322	9	0
Alanine	g	0.427	9	0
Aspartic acid	g	0.617	9	0
Glutamic acid	g	4.743	9	0
Glycine	g	0.495	9	0
Proline	g	1.459	9	0
Serine	g	0.667	9	0

3.4 Processing

As with bread wheat durum wheat requires four processes prior to end product use; cleaning, tempering, milling, and purifying. Cleaning is required to remove weed seeds, dirt and other extraneous material through machines which separate by size (separator), specific gravity (destoner and gravity table), and shape (indented cylinder). Frictional cleaning equipment (scourers) scours the surface of the kernel, removing the outermost layers of the bran. Tempering involves the addition of water which is added to toughen the outer bran coats for easier separation from the endosperm. Tempering also mellows the endosperm for grinding. Traditionally, durum wheat is tempered for a relatively short time. Milling is the simple process of grinding and separating the endosperm (called 'semolina') from the bran and the germ to provide a relatively pure semolina. In general, the semolina is composed of approximately 83% of the durum wheat kernel. Desirable characteristics for semolina include good color, few dark or bran specks, and uniform granulation. Purification is usually carried out during the milling process.

3.5 Cultivar short list

Selection of the Canadian durum wheat cultivars was performed through consultation with Dr. Mark Jordan, Canadian Cereal Research Centre, Agriculture and Agri-Food Canada (AAFC) in Winnipeg, MN. In general, there are no major differences in the yield or protein content between all the currently grown Canadian durum wheat cultivars, and little information is available on a number of the generalized crop selection parameters (see **Error! Reference source not found.**).

Tab. 6 Generalized crop selection criteria

Requirement s	Criteria	Major parameter(s)	Associated parameter	Use in Selection
Physical - system volume Operational - automation	Crop cultivar stature	Growth space	Handling (harvest)	N/A - Very little differ available cultivars how one semi-dwarf cultiva suitable and is include trial selections
Performance – food quantity	Crop cultivar target environment	Growth efficiency	Available light levels (energy); CO_2 level - supplementation	N/A - The most recent cultivars are optimized efficiency in the field a there is little difference between them
Performance – temporal food availability		Growth period length	Crop senescence	N/A – All available cu have similar growth pe
Operational – BLSS interface	Cultivar harvest index	Waste production	Waste degradability	N/A – limited informa available
Functional – produce crops		Influence of plant growth system		N/A – limited informa available
Performance – food quality	Cultivar nutritional composition	Absence of anti-nutritional compounds	Pro-nutritional compounds	N/A – limited informa available
Performance – food quality	Cultivar edible part composition	Processability	Possible conflict with levels of pro-nutritionals	N/A – cultivars have b bred for ease of proces
Performance – food quality		Storage stability	Storage time	N/A – no difference be cultivars
Performance – food quality		Palatability		N/A – current cultivars bred for optimal palata
Performance – food quantity Interface – BLSS	Water use efficiency	Maximum water use Increases growth efficiency	High water turnover rate – regeneration rate	N/A - limited informat available. Durum whe generally bred for arid conditions
Interface – BLSS		atmosphere regeneration capacity	O2 production	N/A - limited informat available
Performance – food	Volatile organic	Ethylene	Growth inhibition	N/A - limited informat

quantity	compound (VOC) production			available
Performance – food quantity	Root exudate production	Allelochemical inhibiting plant growth	Interspecies compatibility	N/A - limited informat available
Human factor – crew time Operational - automation	Labour requirement	Unlikely to find large difference for this parameter	Monitoring sowing transplanting	N/A – no difference be cultivars
Operational – degraded mode	Resistance to stress	Abiotic stress	Recovery from hardware malfunction	N/A - limited informat available
Performance – quantity / availability		Biotic stress	System cleanness maintenance	N/A - limited informat available
Functional – crop production	Pollination	Self-pollinating cultivar requirements		N/A – all cultivars are pollinating
Human factor – crew time Physical – system	Propagation	Seed to seed or vegetative	Seed handling/storage	N/A – all cultivars are from seed
Operational	*Behaviour in extraterrestrial conditions*	*Reduced gravity / reduced pressure*	*Radiation influence*	N/A - limited informat available

Durum wheat is a cultivated grass species that does well in arid conditions, however little is known about its growth response in controlled environments. For this reason, durum wheat varieties with a range of gluten indexes were chosen to ascertain if this parameter is altered by optimal water status. As well, durum wheat cultivar growth habits consist of two main types: normal height (84-100cm) and semi-dwarf (75-80cm). The cultivars selected were Avonlea, Strongfield, Commander, and Eurostar. Avonlea, Strongfield, and Commander are currently in production in Canada whereas Eurostar is a newer variety available for large scale production in the 2009 season. Eurostar was bred to specifically meet European quality specifications and has a high gluten content. Growth habit and gluten index assessments for the selected cultivars are shown in Tab. 7. This data is summarized from field trials where conditions are optimized for ideal growth and development.

Tab. 7 Durum wheat cultivars recommended for food characterization trials.

Cultivar	**Habit**	**Gluten Index (relative)**	**Maturity (days)**	**Protein % (field trial data)**	**Yield tonnes/ha (field trial data)**
Avonlea	Tall	Low	101	14.3	3.6
Strongfield	Tall	Medium	102	14.5	3.6
Commander	Semi-dwarf	High	102	13.8	3.6
Eurostar	Tall	High	104	14.3	3.6

3.6 References

Quaglia GB, **1988**. Other durum wheat products. In: *Durum: Chemistry and Technology*, G Fabriani and C Lintas, eds. American Association of Cereal Chemists, St. Paul, MN. Pp 263-282.

Bushuk, W; Rasper, Vladimir F. **1994**. Wheat: Production, Properties and Quality. Springer.

Kulp, Karel; Ponte, Joseph G. **2000**. Handbook of Cereal Science and Technology, CRC Press.

Feldman M **1976** Wheats. In: Simmonds NW (ed) Evolution of crop plants. Longman, London, pp 120-128.

B.C. Curtis, S. Rajaram and H. Gómez Macpherson. **2002**. Bread wheat Improvement and production. In: FAO Plant Production and Protection Series 2002 567 pg

Canadian Durum: The milling and pasta making process. Undated. Canadian Wheat Marketing Board.

4 Potato (UGent and UCL)

4.1 Introduction

Potato (*Solanum tuberosum*) is the fourth most important food crop cultivated in the world and has an important place in the human diet.
A lot of research has been realised on potato field cultures, but unfortunately these growing conditions are not comparable to the targeted conditions of closed environment culture in substrate-less hydroponics. Hence the results from field-culture are not directly transposable, and a ranking exercise based on these field-derived data will not further allow crop selection in the needed direction for efficient hydroponic culture.
Only a limited amount of research has been carried out (and published) on hydroponic culture of potato, hence knowledge is still limited. In addition it is also difficult to compare the results of the reported experiments as both cultivars and growing conditions are in most cases different.
The information at our disposal, from scientific publications, from internet sources and from an UGent consultant using hydroponic culture to produce small seed potatoes (HZPC bv, NL), has allowed us to identify the key criteria for successful potato production in hydroponics.

4.2 Selection approach

In pre-tests, potatoes were grown successfully to tuberisation, and observations as provided by the UGent consultant HZPC were confirmed
Given the above-described limitations concerning data availability, the development of a short-list of four cultivars presenting different phenotypes and end-usage characteristics, and known to perform well in greenhouse-based hydroponics, is detailed in the following sections; these cultivars will be used for the planned bench test.
First the generalised criteria were amended regarding potato cultivation (Tab. 8). Based on this first assessment, key criteria were defined: maturity (growth period), yield, tuber dry weight, height and disease resistance.
Depending on the results that will be obtained in this bench test using the above-mentioned, on diversity based cultivar selection approach, we will be able to refine our cultivar selection, possibly including other currently unavailable cultivars identified as being of potential interest (to obtain the FC goals in the most efficient way) given their particular characteristics (Astérix, Bartina, Jupiter, Rodeo, Van Gogh, Volumia).
A bench pre-test carried out at UGent allowed to measure the growth and morphology of 5 cultivars with diverse growth habits (for both shoot and tuber formation) as obtained from HZPC as tubers (Bintje, Berber, Carlita, Désirée and Felsina) in controlled hydroponic conditions.

In the upcoming bench-test experiment additional parameters will be measured including CO_2 consumption (and production at night), production of O_2 and ethylene emanation, acid and base consumption for the adjustment of pH, and plant transpiration. Nutritional analysis of the harvested tubers will be carried out by FC project partner IPL (B). As such quantitative data will be available a mathematical selection approach will be used to obtain a selection of cultivars to be used in follow-up growth experiments (including the future PCU hardware).

Tab. 8 Generalized crop selection criteria

Requirement s	**Criteria**	**Major parameter(s)**	**Associated parameter**	**Use in Selection**
Physical - system volume Operational - automation	Crop cultivar stature	Growth space	Handling (harvest)	-N - Height will be regulated by adjustment of the composition of the nutritive solution (HZPC) -Architecture / branching
Performance – food quantity	Crop cultivar target environment	Growth efficiency	Available light levels (energy); CO2 level supplementation	Y Limited information available, advise of HZPC on cultivar NFT adaptability used
Performance – temporal food availability		Growth period length	Crop senescence	N Cultivars selected have different growth period
Operational – BLSS interface	Cultivar harvest index	Waste production	Waste degradability	N potato waste is easily degradable (HZPC info)
Functional – produce crops		Influence of plant growth system		N hydroponic nutrient solution composition modulates shoot/root versus tuber production
Performance – food quality	Cultivar nutritional composition	Absence of antinutritional compounds	Pronutritional compounds	N old potato races with high flavonoid contents could be considered later
Performance – food quality	Cultivar edible part composition	Processability	Possible conflict with levels of pronutritionals	Diversity is taken as initial approach
Performance – food quality		Storage stability	Storage time	N - limited information Available. Depends on harvest strategy
Performance – food quality		Palatability		N cultivars are divided into classes depending on end use. All current cultivars are bred for optimal palatability associated with the processing method of their class; Diversity was chosen as a first approach

Performance – food quantity Interface – BLSS	Water use efficiency	Maximum water use Increases growth efficiency	High water turnover rate – regeneration rate	Data not available
Interface – BLSS		atmosphere regeneration capacity	O2 production	Idem
Performance – food quantity	Volatile organic compound (VOC) production	Ethylene	Growth inhibition	N – only very limited information available
Performance – food quantity	Root exudate production	Allelochemicals inhibiting plant growth	Interspecies compatibility	N – only very limited information available
Human factor – crew time Operational - automation	Labour requirement	Unlikely to find large difference for this parameter	Monitoring sowing transplanting	No difference between cultivars expected
Operational – degraded mode	Resistance to stress	Abiotic stress	Recovery from hardware malfunction	N - limited information available
Performance – quantity / availability		Biotic stress	System cleanness maintenance	Taken into account, mostly qualitative information
Functional – crop production	Pollination	Self-pollinating or cultivar requirements for mechanical pollination		N - No need for pollination in potato
Human factor – crew time Physical – system	Propagation	Seed to seed or vegetative	Seed handling/storage	N - all cultivars can be grown from in vitro plants or from certified small seed tubers (from true potato seed – TPS - is not currently established as an alternative)
Operational	*Behaviour in extraterrestrial conditions**	*Reduced gravity / reduced pressure*	*Radiation influence*	Only few publications available

**Italics: not to be considered in this stage of the research*

4.2.1 Key parameters taken into account

Cultivars bred for human consumption have nowadays similar nutritional characteristics, mainly the dry matter (and thus starch) content differs, hence the division among classes (see 4.2.3 below). The possibility can be considered to introduce additional nutritional diversity (e.g. antioxidant content) by considering old potato races, but these are however known to be limited in yield.

The following criteria are considered to be most important

1. Nutritional quality: DIVERSITY
2. Processability: DIVERSITY
3. High Yield (tuber size combined with number of tubers)
4. Growth habit suited to space constraints / dwarf stature – can be controlled by nutrient solution composition. Plant height to be minimised.
5. Maximum HI / edible portion - can be influenced by nutrient solution composition. Minimization of root growth is an immediate target for improvement.
6. Short growth cycle: HARVESTING STRATEGY to be determined, single end-harvest as a starting point. Growing period – to be minimized if possible.

4.2.2 Specific potato growth requirements

- root zone light exclusion (avoid toxic compound –glycoalkaloids- accumulation, associated with greening)
- stolon growth (genetically determined)
- tuber induction (starvation of nitrogen)

4.2.3 Processing classes

FC project partner IPL (Brussels, B) provided the following division of potato cultivars based on end usage target

A	Low starch	"Annabelle", Charlotte, Nicola
B	Multifunctional	"Felsina"
C	high starch	"Bintje", "Desiree"

A first preliminary UGent conditioned chamber test with the Charlotte cultivar (Class A)– proved successful tuberization induction in hydroponic gullies.

4.2.4 HZPC Consultancy

HZPC (NL) had 67 cultivars readily available, of which
20 cultivars are grown in hydroponics and from which observations are available
Marketing classes of potato cultivars (www.hzpc.com)

1. "Salad" (firm): fresh market – table potatoes
2. "Versatile"
3. "cooking, French fry…"

These classes are thus roughly equivalent with the above defined A/B/C classification.

4.2.4.1 Information and advice provided by HZPC consultancy

The height of potato plants is easily controlled by the amount of nitrogen included in the nutritive solution; it is possible to determine the length of the plants as wanted.
The easiest way to induce efficient tuberization is to provoke plant nitrogen starvation.

Some potato cultivar plants can be kept alive for 3 years (e.g. Desiree), and will produce tubers all along with a little decrease of yield with time. Upon harvest nitrogen has to be added.

Tubers mainly appear when the stolon meets an obstacle, a physical stimulus seems needed for efficient tuberisation.

Tuber shape can become aberrant in hydroponics because of the lack of back-pressure form a (soil) substrate. Not all cultivars display the same sensitivity.

Streptomyces bacterial pathogens (Streptomyces spp.) can cause tuber deformation in hydroponics. Other pathogens are less likely to occur based on the experience of HZPC.

The cultivars Desiree and Innovator grow well in hydroponics, and Innovator has the added benefit that the shoot naturally branches (thus keeping a low compact plant stature).

The Felsina cultivar is mainly eaten as French fries because of its lower quality, and develops tubers that have tendency to de-differentiate into stolons (re-growth from existing tubers), resulting in a network of connected potatoes of low quality. These two points have led to us to remove this cultivar from our selection list for hydroponic culture.

The Carlita cultivar is characterized by a lower taste quality, better alternatives are available (Carlita is still grown, but mainly for the Spanish market).

Vitelotte, which is an old (closer to the wild ancestors of the cultivated potato) purple tuber cultivar rich in antioxidants, generates a lot of shoots and leaves but does not yield many tubers.

Tab. 9 Potato cultivar selection table with freely available data and HZPC input.

Cultivar	tuber shape	tuber size	cooking type	starch content	taste
Annabelle	Long-oval	Undersized	A=very good, firm/Salad		very nice
Berber	Oval	Medium large to large tubers	B=Waxy		
Carlita	Round-oval	Very large tubers.	multi purpose, salad		
Desiree	oval to round	Large sized tubers	multi-purpose type	medium	moderate to good
Felsina		Medium large to very large tubers	multi-purpose type		
Innovator	oval to longlarge	Large sized tubers	good, multipurpose,baking, frying, boiling		very good
Van gogh	oval	Medium large to very large tubers	multi-purpose type	high	moderate
Russet burbank	long to oval/long	Medium large to very large tubers	multi-purpose type	medium to high	good
Bintje	medium to large		multi purpose type	medium	good to excellent
Denali	oval		french fries	medium	good
Norland	oval to round/oblong	large/medium	multi purpose type	medium to high	
charlotte	long to oval	medium to large	salad, firm, waxy, roasting, boiling	low	good to excellent

Cultivar	Maturity	Field yield	Hydroponic yield	dormancy period	Dry matter content	stolon length
Annabelle	Very early	good to high	very high	Very short dormancy	18,4% low	
Berber	Early	good to high		Short	20%	
Carlita	Early	high to very high		long to very long	18,5% low to medium	
Desiree	intermediate to late	medium to very high		medium to long	21.40%	very short
Felsina	early intermediate	high to very high		medium to long	23,6% medium to very high	
Innovator	early intermediate	medium	medium	long	21.30%	
Van gogh	intermediate to late	high to very high	high	medium to long	23.60%	
Russet burbank	early to intermediate/very late/long	medium to very high		Long to very long	22.60%	
Bintje	early to intermediate	high to very high	low	medium	medium high	long to very long
Denali	early	high to very high	very high	long	very high	
Norland	intermediaire to late 75 to 85 days	high to very high/high		short	medium to high	
charlotte	early/early to intermediate	medium to very high		medium to long	medium	

Cultivar	drought resistance	foliage cover	flower frequency
Annabelle		good	
Berber		good	
Carlita	high to very high	poor to dense	occasional
Desiree	high to very high	moderate to dense	frequent
Felsina		moderate to dense	rare
Innovator			frequent
Van gogh	high to very high	good to dense	frequent
Russet burbank	medium	good to dense, tall	occasional
Bintje		moderate to goog	rare to occasional
Denali		moderate to good	
Norland		good	
charlotte			occasional

Tab. 9 describes the characteristics of 12 cultivars from which data was available, on which a first preliminary selection was based. White = not available from HZPC. Yellow and blue: available from HZPC. Blue = identified by HZPC as likely most suited to hydroponics.

Cultivars as used during the HZPC-greenhouse and UGent-growth chamber pretests:

Greenhouse growth trial Sep-nov08	Pre-test UGent growth chamber
Annabelle Saline	Carlita Berber
Desiree (Red skinned)	Desiree (Red skinned)
VanGogh	Felsina
Innovator	Bintje

4.2.4.2 HZPC greenhouse pre-test results

The information from Tab. 10 was derived from the data gathered during the HZPC greenhouse test (Fig. 6), as well as from the UGent growth chamber pre-test.

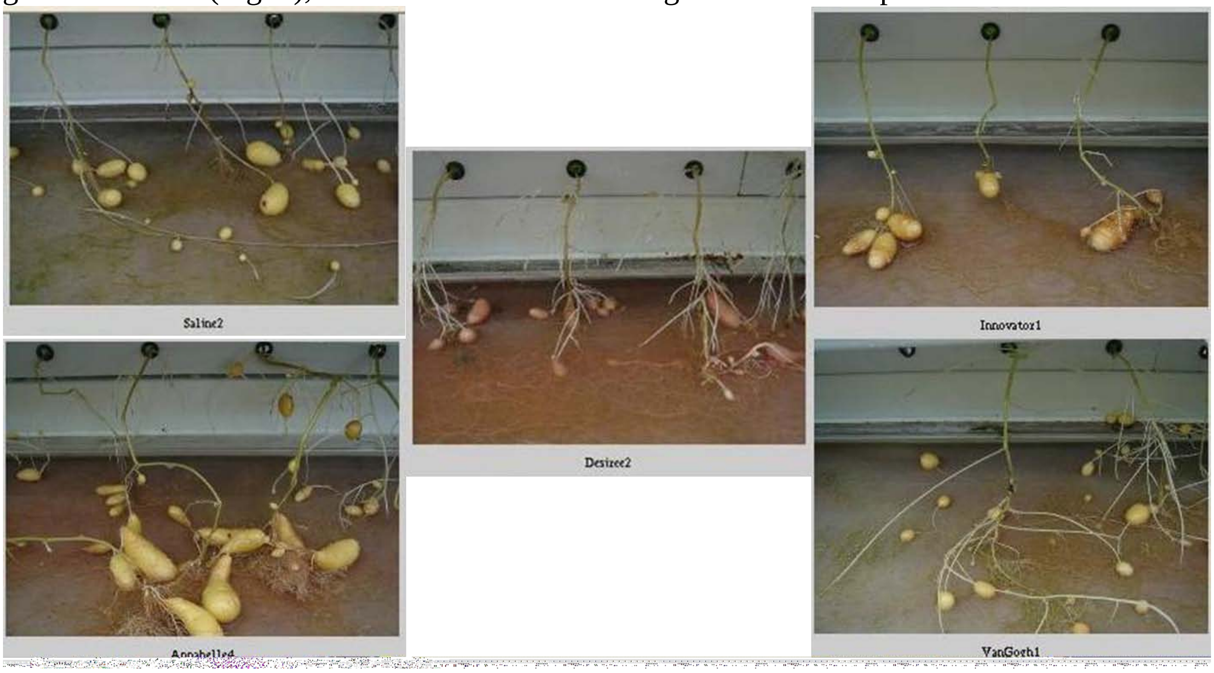

Fig. 6 Root, stolon and tuber development during HZPC pretest

Tab. 10 Overview selection table of potato cultivars

	HZPC	HZPC		Pretest HZPC oct2008				HZPC			
Cultivar	**Yield FW (hydroponics)**	**Yield (hydroponics) FW relative %**	**DW in field**	**Stolon type**	**# tubers/ tuber size**	**Skin colour**	**Flesh colour**	**Shoot growth**	**Maturity**	**Dormancy**	**Disease resistance**
Annabelle	Very high	100	Low 18.40 %	9/plant, Long, single tuber	High (9.5/plant), undersized	Yellow	Yellow	Medium high	Very early	Very short	Middle
Bintje	Low	30-50	Medium to high	Long	Medium to large	Yellow	Yellow	Medium	Early to intermediate	Medium	Low
Desiree	Medium	70	21.40 %	15/plant, Middle length, single tuber	9.9/plant, large	Red	Yellow	Medium	Intermediate to late	Medium to long	High
Innovator	Medium	80-90	High 21.3%	6/plant, Short, single tuber	4.7/plant, small to large	Yellow with brown mottled patern	White	Low	Early to intermediate	Long	Middle
Saline	Very high	100-110	20.30 %	6.6/plant, Long,multiple tuber per stolon (chain)	4.5/plant, small to large	Yellow	Yellow	Low	Early	Long	Middle
Van Gogh	High		23.60 %	9.5/plant, Long	9.4/plant, medium	Yellow	Yellow	Medium to very high	Intermediate to late	Medium long	
For future consideration											
Asterix			High 22.90 %		High, large	Red	Light yellow	High	Intermediate to late	Short to medium	Medium
Rodeo			21.50 %		Large	Red	Yellow		Medium late	Long	
Bartina			18.40 %		Large	Red	Yellow		Early intermediate	Long	Low
Volumia					Very large	Light yellow	Crème			Short	Middle
Jupiter											
Indicative yield closed chamber											
DM m2	1409g/m2	Norland	Mackowiak 1997, Adv. Space Res, 20, 2017-2022 Hydroponic potato production on nutrients derived from anaeronically processed potato plant residues (NASA research)								

Comparison of young tubers from hydroponics versus mature tubers from field culture

Clearly, hydroponic culture has the tendency of decreasing DW%. For the results presented in Tab. 11, the effect is more pronounced since the tubers were not yet mature (and hence starch build-up did not reach its maximum).

Tab. 11 Dry weight content of potato cultivar tubers and ranking

	TUBERS% -HZPC.nl		TUBERS% -EXP	
Annabelle	18.4	5	11.7	5
Desiree	21.4	2	13.8	3
Innovator	21.3	3	16.7	1
Saline	20.3	4	12.7	4
Van Gogh	23.6	1	14.0	2

4.3 Summary of the 4 selected cultivars' characteristics

The literature information, consultancy advice and growth pre-test derived information made it possible to pre-select four potato cultivars (Annabelle, Bintje, Désirée and Innovator) for the bench test experiments, in order to test the outcome of hydroponic growth under artificial light in closed NFT hydroponic culture. Yield is expressed as fresh and dry weight (FW and DW).

Tab. 12 Potato cultivars selected – Key parameters

Cultivar	Tuber FW yield (HZPC hydroponics)	Tuber DW yield –(field)	Tuber size	Plant height	Maturity
Annabelle	Very high	Low 18,4%	Small	Medium-High	Very early
Bintje	Low	Medium to high	Medium to large	Medium	Early to intermediate
Desiree	Very high	21,40%	Large	Medium	Intermediate to late
Innovator	Medium	High 21,30%	Large	Medium to low	Early to intermediate

4.4 Possible future directions

Potato cultivars with red skin generally perform well in hydroponics (HZPC observation) – presumably through an unidentified factor in their genetic background.
Plant architecture determines the relative leaf area shaded by other leaves (and thus degree of self-shading). Shaded leaves are much less efficient than leaves directly exposed to the light source, hence minimization of shaded leaf area, likely in combination with a small plant stature (reduced height, compact architecture caused by branching) could be a valuable selection parameter.
Potato cultivar lines displaying such characteristics, but for which seed potatoes are currently not available due to lack of commercial success can possibly be considered depending on the upcoming results with the 4 cultivars comparative bench-test (Tab. 12)

4.5 References

Mackowiak, C. L., G. W. Stutte, et al. (1997). "Hydroponic potato production on nutrients derived from anaerobically-processed potato plant residues." Life Sciences: Life Support Systems Studies-I **20**(10): 2017-2022.

Rolot, J. L. and H. Seutin (1999). "Soilless production of potato minitubers using a hydroponic technique." Potato Research **42**(3-4): 457-469.

Wheeler, R. M. (2006). " Potato and Human Exploration of Space: Some Observations from NASA-Sponsored Controlled Environment Studies." Potato Research **49**: 67-90.

5 Soybean (UNapoli)

5.1 Introduction

This document contains the review of literature for state of the art about characteristics, environmental needs and cultivation of soybean. It also describes the development of a methodology for objective selection of soybean cultivar based on the requirements documented in the document “Proposal for MELiSSA Food Characterisation Phase 1” RFQ NUMBER: RFQ/3-12471/08/NL/JC.Clearly many of these parameters are not available in literature/from breeders for the preliminary selection of cultivars, but will be used for successive comparison. Moreover, the selection method will be refined during other iterations if needed, considering that it appears unlikely that the relevant criteria and their relative weight can be properly selected at the very beginning.

This document reports a literature review of: a) the availability and admission of soybean cultivars in European Union Countries, b) growth environmental needs of UE admitted cultivars, c) a summary of the information available from cultivation trials carried out on some soybean cultivars in European Union Countries, d) a summary of the available information for UE admitted cultivars, e) a brief summary of the procedure ideated for the elaboration of the methodology for cultivar selection, f) a brief summary of the formula created for cultivar selection and the final list of the cultivars ordered according to their score in decreasing order.

5.2 Literature review on soybean: botanical characteristics and cultivation

5.2.1 Botanical characteristics

Family: *Fabaceae*
Genus: *Glycine(Soja)*
Species: *G. max* (L.) Merr. (*Glycine hispida (Moench) Maxim. Soja hispida Moench*)
The genus *Glycine* was originally introduced by Linnaeus (1737) in his first edition of Genera Plantarum. The term *glycine* is derived from the Greek *glykys* (sweet) and likely refers to the sweetness of the pear-shaped (*apios* in Greek) edible tubers produced by the native North American, *Glycine apios*, now known as *Apios americana*. The cultivated soybean first appeared in the *Species Plantarum*, written by Linnaeus, under the name *Phaseolus max* L. At present, the combination, *Glycine max* (L.) Merr., as proposed by Merrill in 1917, is the valid name for this species (http://en.wikipedia.org).

5.2.2 Biology and yield

Soybean is an annual plant. The root system is composed by a taproot and many secondary roots spreading throughout the soil. After germination, many adventitious roots are developed. Although the principal root generally prevails on the secondary ones, the root system is considered as fasciculated or with slight tap-root. This is consequent to the peculiar architecture of the root system of plants cultivated in the field with soil as substrate. In such conditions, the root system is mostly represented by secondary roots, which first grow horizontally for 40 cm, then they go deep in the soil up to 150 cm.If soil depth is restricted, the tap root is less evident and lateral roots are more developed (www.fao.org).

Soybeans, like most legumes, perform nitrogen fixation by establishing a symbiotic relationship with the bacterium *Bradyrhizobium japonicum* (syn. *Rhizobium japonicum*).

The bacterium starts the formation of nodules when the primary root hairs begin their elongation. Nodules are visible 7-9 days after infection; their growth usually stops when they reach a diameter of 4-6 mm. An adult plant is characterised by many nodules with different age and size.

The pods, stems, and leaves are covered with fine brown or gray hairs. The stem can reach up to 150 cm height and is widely branched.

Soybean cultivars may have undetermined or determined development. In the former type, plants continue to grow for several weeks after the beginning of flowering and they haven't a terminal raceme but only axillaryinflorescences; they may have 7-12 nodes. The determined types have a terminal raceme and their growth ends at flowering; as a consequence they are shorter (5-8 nodes).

Soybean has different types of leaves: apart from the cotyledons, plants present primary simple leaves (oval and opposite) and trifoliate hairy leaves characterised by alternate distichous disposition. Stomata are on both the adaxial and abaxial sides of the lamina, but their frequency is higher on the abaxial surface.

Generally, leaves are shed before pod ripening, when seeds have more than 20% humidity.

Flower morphology is typical of the Fabaceae family, with 5 red or white petals, arranged in a butterfly-resembling structure. Flowers are joined in racemes containing 2 to 35 flowers. They firstly bloom on the stem base. Usually, from 20 to 80% of flowers abort, especially in cultivars characterised by many flowers per node. The flowering period may last 3-5 weeks or more, depending on the cultivar and sowing age. Soybean is an autogamous species; heterogamy is less than 1%.

The pods are little, straight or slightly curved, covered by long hairs; their colour can vary from pale yellow to gray, brown or black. Each pod contains 1-5 seeds.

The seed shape can vary with the cultivar, but in the most cases it is round or elliptic. Seed colour can be pale yellow, grey, green, brown or black. Seed size is variable (the weight of

1000 seeds ranges between 50 and 450 g). The bigger seeds are usually used in human nutrition.

Germination happens 5 -10 days after sowing, provided that the soil moisture conditions and temperature are adequate. Nitrogen-fixation starts 14-19 days after seedling establishment. More than 80% of nitrogen is fixed between flowering and green ripening of the seed. The amount of fixed nitrogen is 80-120 kg/ha, depending on agricultural and environmental conditions. Data available on the amount of fixed nitrogen also depend on the system used for the measurement.

For most of commercial cultivars, life cycle (from sowing to harvesting) lasts 80–120 days.

Seeds are ready to be harvested when pods are completely ripened and seeds' humidity is about 12-14 %. Seeds must be stored for a season (humidity 14%), 1 year (humidity 13%), about 3 years (humidity 12%) or about 4 years (humidity 10%).

Grain yield can be 30-35 q/ha.

5.2.3 Environmental requirements

Climatic requirements of soybean are similar to those of maize. The minimal temperature for growing is about 4-6 °C; a mean temperature of 24-25 °C seems to be the optimum for most cultivars. Lower temperatures determine delays in the flowering.

Considering photoperiod, soybean is a short-day plant, but response to day-length varies according to the cultivar and temperature: many cultivars need ten hors of dark in order to bloom. All cultivars bloom faster if photoperiod corresponds to 8 hours a day.

Soybean is sensitive to deficit in water availability in particular phases of its cycle. If the water shortage is experienced during the flowering or at the beginning of the pods' formation, there can happen flowers' abortion and pods' shedding. A long flowering time allows the plant to tolerate low levels of water deficit. The maximum decrease of seeds' production occurs when water deficit is experienced during the last week of pod development and during seed formation. Less damage occurs at the beginning of flowering and in the final stage of seed formation.

Soybean can grow in a wide range of soil types: from clayey to organic and poorly fertile. Optimum pH of soil is 6 to 6.5. (Baldoni and Giardini, 1989; http://en.wikipedia.org)

The species is sensitive to waterlogging, but moderately tolerant to soil salinity. Yield decrease due to soil salinity is: 0% at ECe 5 mS/cm, 10% at 5.5; 25% at 6.2; 50% at 7.5 and 100% at ECe 10 mS/cm (www.fao.org).

(All information included in paragraphs 3.2 and 3.3 were summarised from the following resources: Baldoni and Giardini, 1989; http://en.wikipedia.org)

5.2.4 The history of soybean in Europe

Soybean was probably introduced in Europe in the early 1700s. It is known to have been grown in the Netherlands since 1737, in France probably since 1739 or 1740 (certainly since 1779) and in England since 1790.
Interest in soyfoods in Europe has since steadily increased (www.soyinfocenter.com).
At present soybean is mainly cultivated in USA, Brazil, China, India, Argentina and Italy.
Soybean is the most diffused genetically modified species whose distribution is forbidden in Europe, while in USA it represents the 50% of the total yield and in Brazil the 64% (www.diwinetaste.com).

5.2.5 The present situation of soybean cultivation in the EU

Currently, Italy, Romania and France are the countries characterised by the highest soybean harvested area, yields and productions.

Fig. 7 shows the trend of fields dedicated to soybean cultivation in the last ten years in different European countries. The higher value of area harvested is always reached in Italy, even if it has been decreasing since 2001. In Romania it has been increasing since 2002, attaining about 114.000 ha in 2007. In France, the area has been progressively reduced, and in 2007 it was 37000 Ha, like the other countries which have a harvested area lower than 40.000 ha.

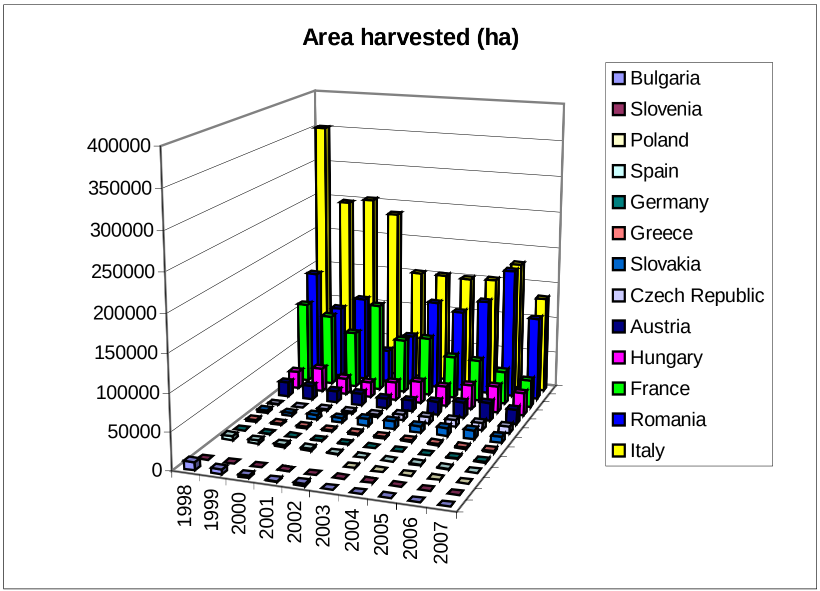

Fig. 7 Soybean Area Harvested (ha) in EU Countries from 1998 to 2007
FAO estimate - FAOSTAT - © FAO Statistics Division 2009 - 11 February 2009

Regarding yields, since 1998, they have also been the highest in Italy. Fig. 8 shows yields obtained in 2007.

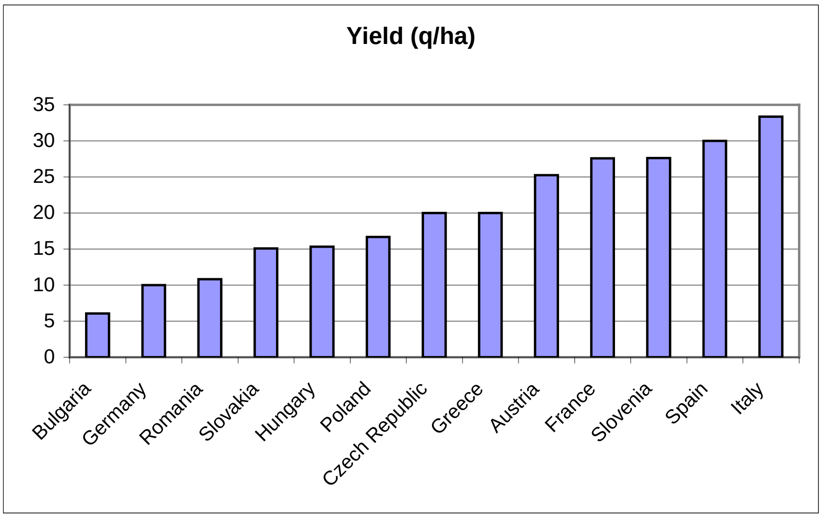

Fig. 8 Soybean Yield (q/Ha) in the year 2007
FAO estimate - FAOSTAT - © FAO Statistics Division 2009 - 11 February 2009

The trend of soybean production is similar to that of the area harvested. Fig. 9 shows that the highest production is obtained in Italy, although the amounts decreased from 2001. Romania is the second country in terms of production, with an increasing amounts starting from 2001. In 2007, Romania reduced the production, reaching the amount of France.

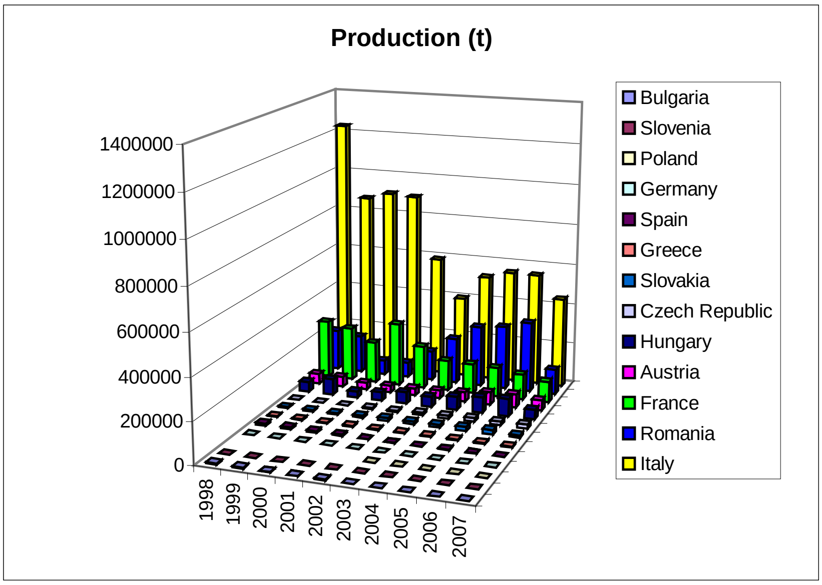

Fig. 9 Production (t) of soybean in the EU countries from 1998 to 2007

FAO estimate - FAOSTAT - © FAO Statistics Division 2009 - 11 February 2009

Although Romania seems to have an important role in soybean cultivation, we must remember that its admission in the EU happened in 2007 and probably, before that year, the most cultivated soybean cultivars were represented by genetically modified organisms (GMO) (www.osservatoriobalcani.org; www.balcanicooperazione.it).

Currently, Romania has admitted only 2 soybean cultivars and its Agriculture Department would like to cultivate again GM soybean (www.terramultimedialeagricoltura.it).

According to the Official Journal of the European Union of 20.11.2008 (http://eur-lex.europa.eu/), the total number of soybean cultivars admitted by the EU is 297.

The following table (Tab. 13) shows the percent distribution among the EU countries. The countries which admitted the most of soybean cultivars are Italy (49%), Hungary (14%) and France (14%).

Tab. 13 Soybean cultivars admitted by EU: percent distribution in member countries

COUNTRY	TOT (%)
Romania	0.6
Germany	1.4
Poland	1.4
Bulgaria	2.0
Czech Republic	2.3
Spain	2.6
Slovakia	6.1
Austria	7.2
France	**13**
Hungary	**14**
Italy	**49**

5.2.6 Cultivar availability: the EU present situation

We searched for information about the main companies and the most commercialized cultivars. We searched them on the internet and directly contacted them either by direct phone contacts and mailing.

Number of companies found = 26

Number of companies contacted = 23

Number of companies which furnished information =13

Gained information is reported below:

5.2.6.1 Information on cultivars admitted in Italy

These cultivars are not necessarily exclusive for Italy

CONDOR medium cycle (group 1)

- Branching: good
- Defoliation: rapid
- Dehiscence: tolerant
- Destination: 1st cropt (also late sowing)

- Hilum: fair/light
- Insertion of the first pods: high
- Recommended for any kind of soil and for all the environments
- Resistance to lodging: high
- Resistance to *Phytophthora*: good
- Size: medium
- Stability: excellent
- Plants/Final: sq. mt. 38 – 40
-

Note that the colour of hilum (area that joins the seed and the pod) is a fundamental characteristic of soybean cultivars destinated to the human nutrition: a colourless or fair hilum is preferred to avoid the coloration of transformed products, expecially tofu.

TEA medium cycle (group 1)

- Branching: good
- Defoliation: rapid
- Dehiscence: resistant
- Destination: 1st crop
- Hilum: fair/light
- Insertion of the first pods: high
- Resistance to lodging: good
- Resistance to *Phytophthora*: good
- Size: medium (about 100 cm)
- Suitable highly fertile environments
- Plants/Final: sq. mt. 40 - 42

FORTEZZA medium-early cycle (1-)

- Branching: high
- Defoliation: rapid
- Dehiscence: tolerant
- Destination: 1st and 2nd crop
- Hilus: fair/light
- Insertion of the first pods: high
- Resistance to *Phytophthora*: good
- Rustic, it adapts the most different cultivations' conditions
- Size: medium - short
- Yield: high
- Plants/Final sq. mt. 43 - 45

BORNEO late group 1

- Dehiscence resistance: scored 9/10
- Destination: 1st crop, anticipate sowing and fertile and fresh soils preferred.
- Disease resistance: scored 8/10
- Drought resistance: scored 7/10
- Hilum: black
- Lodging resistance: scored 7/10
- Size: medium-high, characterized by luxuriant foliage.
- Yield: high, thanks to its large number branchs of pods.
- Plants/Final sq. mt. 35-40

ATLANTIC mid group 1

- Dehiscence resistance: scored 10/10
- Destination: 1st crop
- Disease resistance: scored 8/10
- Drought resistance: scored 7/10
- Fertile soils with high yield potential preferred
- Hilum: black
- Lodging resistance: excellent, scored 9/10
- Seedling vigour: strong
- Yield: high, granted in every environments
- Plants/Final sq. mt. 40-45

INDIAN early group 1

- Closer internodes, rich of many fertile pods
- Dehiscence resistance: scored 7/10
- Destination: 1st and 2nd crop
- Disease resistance: scored 8/10
- Drought resistance: scored 7/10
- Lodging resistance: scored 8/10
- Suitable for all environments
- Yield: scored 8/10
- 1000 seeds weight: high
- Plants/Final sq. mt. 40-45 (1st crop); 45-50 (2nd crop)

AIRES early (group 0+)

- Defoliation: rapid and uniform
- Destination: 1st and particularly 2nd crop
- Level of antinutritional factors: low

- Resistance to lodging: optimal
- Size: medium – short (about 80-90 cm)
- Tolerance to diseases: good
- Yield: high
- Plants/Final: sq. mt. 40-45 (1st crop); 45-50 (2nd crop)

HILARIO medium cycle (group 1)

- Advised for fertile soils
- Defoliation: rapid
- Destination: 1st and 2nd crop
- Level of antinutritional factors: low
- Resistance to lodging: optimal
- Size: medium (about 100 cm)
- Tolerance to diseases: good
- Yield: high
- Plants/Final: sq. mt. 38-42 (1st crop); 42-45 (2nd crop)

ASCASUBI medium cycle (group 1)

- Destination: 2nd crop but it is important to sow promptly
- Level of antinutritional factors: low
- Resistance to lodging: optimal
- Size: medium-high (about 105 cm)
- Tolerance to diseases: good
- Plants/Final sq. mt. 40 – 45 (1st crop); 45-50 (2nd crop)

The duration of its life cycle allows a longer time for accumulation and higher yield.

PEDRO medium-early cycle (group 1-)

- Destination: optimal for 2nd crop
- Defoliation: rapid
- Fertile soils preferred
- Level of antinutritional factors: low
- Resistance to lodging: excellent
- Size: medium-high
- Tolerance to diseases: good
- Sowing density sq. mt. 40 – 45 (1st crop); 50 (2nd crop)

BLANCAS medium cycle (group 1+)

- Destination: only 1st crop

- Level of antinutritional factors: not low, but it is much cultivated due to its high yield
- Resistance to lodging: good
- Size: medium-high
- Tolerance to diseases: good
- Yield: high
- Plants/Final sq. mt. 35-40

Very rustic, it adapts the most different cultivations' conditions and it is particularly good for sowing in rows with 75 cm distance.

COLORADO medium-late cycle (group 1+)

- Destination: 1st crop
- Level of antinutritional factors:very low
- Resistance to lodging: excellent
- Size: medium
- Suitable in very fertile soils
- Tolerance to diseases: good
- Plants/Final sq. mt. 40 – 45

BAHIA medium-early cycle (group 1-)

- Low level of antinutritional factors
- Resistance to lodging: good
- Size: medium-high
- Yield: high

CRESIR (group 0+)

- Adapted to high sowing density: scored 10/10
- Branching: low
- Defoliation: rapid
- Destination: 1st and 2nd crop, sod seeding
- Resistance to lodging: excellent (scored 10/10)
- Seedling vigour: strong
- Suitable for all environments.
- Suitable for sowing with reduced distance between rows
- Tolerance to *Diaporthe*: scored 10/10
- Tolerance to *Phytophthora*: scored 9/10
- Tolerance to stresses: scored 8/10
- Yield: high
- Plants/Final sq. mt. 40-50

It can be also used in organic farming, thanks to its specific resistance to the common diseases, the harvesting advance and the physical grain quality.

PR91M10 (group 0+)

- Adapted to high sowing density: scored 10/10
- Branching: low
- Defoliation: rapid
- Destination: 1st and 2nd crop
- High sowing density preferred
- Hilum: fair
- Protein content: high
- Resistance to lodging: optimal
- Resistance to *Diaporthe* and *Phytophthora*: excellent
- Seedling vigour: strong
- Suitable for organic farming
- Suitable for industrial uses
- Tolerance to stresses: scored 9/10
- Plants/Final sq. mt. 40-50

This cultivar has a very good physical quality of seed (big size, uniform, light hilum) and a high protein content. These characteristics are requested by industry to produce human food. Its cycle allows an early harvesting period and a perfect seeds storage.

PR91B92 (group 1-)

- Adapted to high sowing density: scored 8/10
- Branching: good
- Defoliation: rapid
- Destination: 1st and 2nd crop
- Resistance to lodging: optimal
- Seedling vigour: strong
- Resistance to *Phytophthora*: good
- Tolerance to *Rhizoctonia:* good
- Tolerance to stresses: scored 9/10
- Plants/Final sq. mt. 35- 40

REGIR (group 1)

- Adapted to high sowing density: scored 9/10
- Branching: medium
- Defoliation: rapid
- Destination: 1st and 2nd crop

- Plentiful flowering and short flowering period
- Resistance to lodging: good
- Size: medium- low
- Tolerance to stresses: scored 10/10
- Yield: high, higher than later cultivars (favourable productivity/maturity ratio)
- Plants/Final sq. mt. 35-40

NIKIR (group 1)

- Adapted to high sowing density: scored 10/10
- Branching: good
- Defoliation: rapid
- Fertile soils preferred
- Hilum:fair
- Optimal response to different sowing density
- Resistance to lodging: optimal
- Size: medium
- Stability: good
- Suitable for industrial uses
- Tolerance to *Diaporthe*: good
- 1000 seeds weight: low
- Plants/Final sq. mt. 35-40

PR92B63 (group 1+)

- Adapted to high sowing density: scored 6/10
- Fast development
- Resistence to *Diaporthe*: good.
- Seedling vigour: strong
- Stem soundness: high
- Suitable for sowing along rows distant 70-75 cm
- Tolerance to environmental stresses: very high, suitable for heavy soils
- Tolerance to *Phytophthora*: good
- Yield: very high
- Plants/Final sq. mt. 30-35

PACIFIC (group 1)

- Defoliation: rapid
- Destination: 1st crop
- High yield

- Resistance to diseases: good
- Resistance to lodging: optimal
- Size: medium-high (about 109 cm)
- Yield: high
- Plants/Final sq. mt. 35 – 40

ASKJA early cycle (group 0+)

- Defoliation: rapid
- Destination: also late sowing and 2nd crop
- Hilum: white
- Resistance to lodging: good
- Resistance to *Phytophthora*: good
- Size: medium
- Tolerance to *Diaporthe*: good
- Sowing density sq. mt. 40-44 (1st crop); 44-50 (2nd crop)

BRILLANTE medium cycle (group 1)

- Branching: good
- Defoliation: rapid
- Destination: 1st and 2nd crop
- Hilum :white
- Resistance to lodging: good
- Resistance to *Phytophthora*
- Size: medium
- Yield: good, also in hard environmental conditions
- Sowing density sq. mt. 40-44 (1st crop); 44-50 (2nd crop)

NEOPLANTA (group 1-)

- Defoliation: very rapid
- Destination: 1st and 2nd crop
- Resistance to diseases: high
- Resistance to lodging: exceptional
- Size: medium
- Stability: high
- Plants/Final sq. mt. 50-55

Neoplanta showed excellent results in official trials in Hungary, where it was released under the name of Bacskun. This original name was maintained in Romania, Italy and Croatia.

DEMETRA medium cycle (group 1)

- Branching: absent
- Defoliation: rapid
- Destination: 1st and 2nd crop
- Resistance to lodging: excellent
- Resistance to *Diaporthe*: good
- Resistance to *Phytophthora*: good
- Seedling vigour: strong
- Size: medium
- Yield: high
- Sowing density: sq. mt. 44-48 (1st crop); 48-52 (2nd crop)
- Grains can be easily trashed even under unfavourable conditions

GIULIETTA early-medium cycle (group 1-)

- Defoliation: optimal
- Destination: 1st crop (also late sowing) and 2nd crop; sod seeding
- Resistance to lodging:good
- Resistance to *Diaporthe*: good
- Resistance to *Phytophthora*: good
- Seedling vigour: good
- Size: medium-low
- Sowing density: sq. mt. 40-44 (1st crop); 44-50 (2nd crop)

SHAMA medium cycle (group 1)

- Defoliation: rapid
- Dehiscence: resistant
- Destination: 1st and 2nd crop; sod seeding
- Insertion of the first pods: high
- Protein content: very high
- Resistance to lodging: optimal
- Resistance to *Phytophthora*: good
- Size: medium, short internodes
- Tolerance to *Diaporthe*: good
- Sowing density: sq. mt. 40-44 (1st crop); 44-50 (2nd crop)

5.2.6.2 Information on cultivars admitted in Serbia

The Institute of Field and Vegetable Crops, Novi Sad Serbia uses 3 Italian, 3 Hungarian and 1 Bulgarian soybean cultivars admitted in EU, and it use 3 soybean cultivar that haven't been admitted. The cultivars are reported below:

Hungarian cultivars

ANITA 66 group 00

- Destination: 1st and 2nd crop
- Genetic yield potential: over 4.5 t/ha
- Growing season of 100 - 105 days
- Resistance to lodging: exceptional
- Resistance to *Peronospora manshuric*a: good
- Sowing density sq. mt. 55-60 (1st crop)

MELI group 0

- Hilum:colourless
- Resistance to *Peronospora manshuric*a: good
- Size: medium
- Tolerance to dry conditions: exceptional
- 1000 seeds weight: medium
- Sowing density sq. mt. 50

ALISA group 0

- Destination; 1st and 2nd crop
- Genetic yield potential: over 4.5 t/ha
- Hilum: brown
- Size: medium
- Sowing density sq. mt. 55-60 (1st crop)

Italian cultivars

TEA

NEOPLANTA

CONDOR

For these cultivars, please refer to paragraph 3.6.1.

Bulgarian cultivars admitted in EU

AVILA

- Exceptionally adaptable, suitable for cultivation is all soybean-growing regions in this part of Europe
- Genetic yield potential: over 4.5 t/ha
- Resistance to *Peronospora manshurica*: high
- Sowing density sq. mt. 55-60 (1st crop)

<u>Bulgarian cultivars not admitted in EU</u>

PROTEINKA

- Genetic yield potential: over 4.5 t/ha
- Protein content: high
- Suitable for industrial uses
- Sowing density sq. mt. 55-60 (1st crop)

The cultivar has been officially released in Serbia, Romania, Croatia and Ukraine

BALKAN

- Genetic yield potential: over 5 t/ha
- Yield: high
- Sowing density sq. mt. 45 (1st crop)

The cultivar has been officially released in Serbia, Romania and Bulgaria

VENERA

- Owing to the long growing season, Venera may pass the stress period in the vegetative state and take advantage of late summer rains.
- Oil content: high

The cultivar has been officially released in Serbia, Romania and Bulgaria.

5.2.6.3 Information on cultivar admitted in France

These cultivars are not necessarily exclusive for France

CLARA Group 1

- Destination: early and late sowing
- Hilum: white
- Insertion of the first pods: high
- Protein content: good
- Resistance to lodging: optimal
- Size: short, with few leaves (decrease sanitary risks)
- Yield: high
- Stalk rating: excellent; no risk regarding late harvest

LANCA group End 0 - Beginning 1 (appropriate for early and late area)

- Insertion of the first pods: medium (13 cm)
- Protein content: good
- Size: low
- Stalk rating: excellent; no risk regarding late harvest
- Yield: good

ORLANDA group End I

- Insertion of the first pods: medium to high (14 cm)
- Protein content: good
- Size: low
- Stalk rating: excellent; no risk regarding late harvest
- Yield: high

It has constant yield rating regarding rusticity. It is characterised by high grain production with an excellent protein rating per hectare.

FASTO group 1

- Insertion of the first pods: high (19 cm)
- Protein content: good
- Resistance to lodging: good
- Size: medium-high
- Tolerance to *Sclerotinia*: good
- Yield: high

SANTANA group 1-2

- Dehiscence: resistant
- Hilum: slightly brown
- Insertion of the first pods: medium-high (14 cm) or 12 cm
- Protein content: good (39.5 %)
- Resistance to lodging: good (equal to *Dekabig*)
- Size: medium (85 cm)
- Yield: high (46.8 q/ha)
- 1000 seeds weight: low (172 g)

ALBINOS group 000

- Destination: late sowing and as catch crop in rotations

- Earliness: scored (cultivation trials) 7.5/9
- Hilum: yellow
- Insertion of the first pods: scored 8.5/9 (13 cm)
- Protein content: scored 8.5/9 (42%)
- Resistance to lodging: scored 7.5/9 (quite sensitive)
- Size: scored 6.5/9 (83 cm)
- Suitable for industrial uses
- Yield: scored 8.5/9 (i.e. 35 q/ha)
- 1000 seeds weight: scored 7/9 (213 g)
- Sowing density: sq. mt: 60-70 (irrigated); 65-75 (not irrigated)

DEKABIG group 1

- Earliness: scored 7/9
- Insertion of the first pods: scored 6/9
- Protein content: scored 7.5/9
- Resistance to lodging: scored 8/9
- Size: scored 5.5/9
- Yield: scored 8/9
- 1000 seeds weight: scored 7/9
- Sowing density: sq. mt 40-50 (irrigated); 50-60 (not irrigated)

SHAMA group 1

- Earliness: scored 8/9
- Insertion of the first pods: scored 7/9
- Protein content: scored 8.5/9
- Resistance to lodging: scored 8/9
- Size: scored 6/9
- Yield: scored 8/9
- 1000 seeds weight: scored 8/9
- Sowing density: sq. mt 40-50 (irrigated); 50-60 (not irrigated)

SUMATRA group 1

- Earliness: scored 6/9
- Hilum: brun
- Insertion of the first pods: scored 8/9 (12-14 cm)
- Number of internodes/plant: high
- Number of pods/internodes: high
- Protein content: scored 8/9
- Resistance to lodging: scored 7/9

- Size: scored 8/9 (95-105 cm)
- Suitable for industrial uses
- Yield: scored 8.5/9
- 1000 seeds weight: scored 8/9
- Sowing density: sq. mt 40-50 (irrigated); 50-60 (not irrigated)

PROTINA group 000 (cultivated as catch crop in rotations)

- Earliness: scored 7.5/9
- Insertion of the first pods: scored 7/9
- Protein content: scored 9/9 (not suitable for human feeding)
- Resistance to lodging: scored 8/9
- Size: scored 7/9
- Yield: scored 8/9
- 1000 seeds weight: scored 7.5/9 (169 g)
- Sowing density: sq. mt 60-70 (irrigated); 65-75 (not irrigated)

SEPIA group 00

- Earliness: scored 7.5/9
- Insertion of the first pods: scored 8/9 (12 cm)
- Protein content: scored 7/9 (40%)
- Resistance to lodging: scored 6/9
- Resistant to water stress in the final phase of cycle
- Size: scored 7.5/9 (95 cm)
- Yield: scored 8/9 (36 q/ha)
- 1000 seeds weight: scored 6/9 (186 g)
- Sowing density: sq. mt 55-65 (irrigated); 60-70 (not irrigated)

KLAXON group 000

- Dehiscence: resistant
- Destination: also for late sowing and as catch crop in rotations
- Earliness: scored 9/9
- Hilum: fair
- Insertion of the first pods: scored 7/9 (10 cm)
- Protein content: scored 8/9 (41%)
- Resistance to lodging: scored 6.5/9
- Size: scored 6/9 (75-85 cm)
- Suitable for industrial uses
- Yield: scored 8.5/9 (33.3 q/ha)
- 1000 seeds weight: scored 7/9 (186 g)

- Sowing density: sq. mt 60-70 (irrigated); 65-75 (not irrigated)

SAFRANA group 1

- Earliness: scored 7/9
- Insertion of the first pods: scored 6/9
- Protein content: scored 8/9 (the richest in the group 1)
- Resistance to lodging: scored 8/9
- Size: scored 6/9 (75-85 cm)
- Suitable for industrial uses
- Yield: scored 7/9
- 1000 seeds weight: scored8/9
- Sowing density: sq. mt 40-50 (irrigated); 50-60 (not irrigated) (suitable for high densisy sowing)

SEKOIA group 1

- Dehiscence: resistant
- Earliness: the best of the group 1
- Hilum: brown
- Insertion of the first pods: high (13-14 cm)
- Number of internodes/plant: high
- Number of pods/internodes: high
- Protein content: medium (equal to Dekabig)
- Resistance to lodging: good (equal to Dekabig)
- Size: medium (+10 cm/Dekabig)
- Yield: high
- 1000 seeds weight: scored 7/9
- Sowing density: sq. mt 40-50 (irrigated); 50-60 (not irrigated)

OAC ERIN group 000

- Hilum: yellow
- Insertion of the first pods: high (13-15 cm)
- Protein content: medium (39 %)
- Resistance to lodging: medium (equal to Pronto)
- Size: medium (82.4 cm)
- Yield: high (39 q/ha)
- 1000 seeds weight: low (150-170 g)

5.2.6.4 Information on cultivars admitted in Switzerland

These cultivars are admitted in various EU countries, but were all subjected to cultivation trials in Switzerland

MERLIN group 000 (or 0)

- Hilum: brown
- Oil content: good-medium
- Protein content: good-medium
- Resistance to lodging: good-medium
- Tolerance to cold during the flowering: good-medium
- Yield according to the group: good
- 1000 seeds weight: very low

GALLEC group 000

- Hilum: colourless
- Oil content: medium
- Protein content: good-medium
- Resistance to lodging: good-medium
- Tolerance to cold during the flowering: good-medium
- Yield according to the group: good
- 1000 seeds weight: medium

AMPHOR group 000-00

- Hilum: brown
- Insertion of the first pods: 12 cm
- Oil content: medium-low
- Protein content: good (41.5%)
- Resistance to lodging: good
- Size: medium (78 cm)
- Tolerance to cold during the flowering: medium
- Yield according to the group: good (34.7 q/ha)
- 1000 seeds weight: medium (199 g)

LONDON group 00

- Hilum: brown
- Oil content: good-medium
- Protein content: medium-low
- Resistance to lodging: good
- Tolerance to cold during the flowering: medium-low

– Yield according to the group: good
– 1000 seeds weight: very low

ESSOR group 00

Hilum: colourless
– Resistance to lodging: good-medium
– Tolerance to cold during the flowering: medium
– Yield according to the group: good
– 1000 seeds weight: medium

5.2.7 Clarifications regarding considered characteristics

In this sub-paragraph some clarifications (notes, N) about characteristics considered in the description of the cultivars are reported.

N1) Protein content and processing suitability - Process suitability is a wider concept usually referring not only to protein and other compounds but also to other morphological traits not better specified by industries.

N2) First pod insertion - It is the height/internode at which the first "layer" of fruits is inserted from the ground. It is important mainly for harvesting (P=1).

N3) Destination - It is referred to the period of cultivation (season) and consequently to the requirements in terms of light, temperature and other factors.

N4) Stalk rating - It is referred to the growth rate at the beginning of cultivation.

N5) Defoliation – This parameter was linked to the ease of harvest.

N6) Yield - 1 ton/ha of soybean corresponds to 14.87 bu/A; consequently 154 bu/A correspond to 10.36 ton/ha.

N7) Tolerance to stress – It is referred to both biotic and abiotic stresses but it is not better specified by industries;

N8) The trait "determinate/indeterminate nature of the soybean cultivar" is not included in the selection strategy because information was not available for the considered cultivars.

5.3 Literature review on soybean: cultivation trials and summary of available information

5.3.1 Information from cultivation trials

UNapoli conducted a literature study to search for data about growth environmental needs and yields of soybean cultivars subjected to cultivation trials. Cultivars considered were those reported in the previous paragraph. However, most cultivation trials were conducted on genetically modified cultivars not admitted in EU, while information was available for a limited number of cultivars admitted in EU.

The following table (Tab. 14) summarizes the characteristics of some cultivars admitted in Italy, according to "The official register of varieties of the Italian Ministry of Agriculture", which were subjected to cultivation trials.

In this table, mean values from different trials are reported per cultivar when available. Cultivars in red are not admitted in EU; cultivars in blue are admitted and were tested also in other countries.

Tab. 14 Characteristics of soybean cultivars subjected to cultivation trials

	Group	Yield (t/ha)	Height (cm)	Lodging (%)	1000 seeds weight (g)
BLANCA	1	3,97	94	-	178
CASA	1+	4,91	122	33	-
DEKABIG	1+	4,97	109	20	179
FIUME	1-	4,28	101	18	213
FLY	1+	4,88	119	30	-
FUKUI	1	4,53	94	10	183
GORIZIANA	1	4,44	91	7	216
LORY	1	4,52	97	13	169
MAGNUM	1-	4,94	98	28	166
MANUELA	1	5,19	109	55	-
NIKKO	1-	4,00	91	23	191
NORMA	1	4,87	112	48	-
SAFRANA	1	3,48	79	-	228
SAKAI	1	4,00	110	26	176
SAKE	1-	4,19	114	40	172
SAMURAI	1	4,95	111	42	-
SAPPORO	1	4,61	104	37	189
SAREMA	0	3,50	92	20	191
SEKOIA	1	4,07	99	32	193
SPONSOR	1	4,44	97	28	178
TAIRA	1+	5,07	112	16	187
TOYAMA	1	4,91	126	54	-
ZEN	1	4,72	111	20	180

5.3.2 Summary of available information for soybean cultivars

For the cultivar selection were referred to the “The official register of varieties of the Italian Ministry of Agriculture” and to the “Official Journal of the European Union”. We searched for information about the main companies and the most commercialized cultivars. We searched them on the internet and directly contacted them either by direct phone/fax contacts and mailing. We also searched information from the sources reported in the document “Proposal for MELiSSA Food Characterisation Phase 1” RFQ NUMBER: RFQ/3-12471/08/NL/JC, in particular form Semences Prograin in Canada and OH-Otto HauenStein and ES-Eric Schweizer in Switzerland.

Information for cultivar documented in the previous paragraph derived from different sources, often from different countries. Also cultivation trials were conducted by different farmers and researchers in several places. As a consequence, available information about all the considered cultivars lacks from uniformity, because there is not always homogeneity regarding growth parameters considered and standardization of measuring scales used.

Tab. 15 summarizes per each considered parameter, the number of cultivars for which there is available information. For some specific parameters, data are available only for a few cultivars. It is likely that these parameters will not be considered in the final choice of the candidate cultivars unless they are fundamental for the successful cultivation in an ecologically closed system.

Tab. 16 reports the number of parameters for which there are available data per each considered cultivar. (Cultivars whose information are available also in catalogues are bolded; cultivars admitted and cultivated in more than one European country are reported in blue; cultivars not admitted in EU are reported in red). For some cultivars, data are available only for a few parameters. It is likely that these cultivars will not be considered in the final choice of the candidates unless they present specific parameters that make them particularly suitable for the successful cultivation in an ecologically closed system.

Tab. 15 Number of cultivars for which parameter information is available

Parameter	Number of cvs
Environmental conditions	21
Branching	11
Defoliation	19
Dehiscence (numbers = score/10)	16
Destination	30
Hilum	30
Insertion 1st pods (numbers = score/9)	12
Insertion 1st pods (cm)	29
Sensitivity to lodging (numbers = %plants lodged)	84
Tolerance to Phytophthora (numbers = score/10)	33
Tolerance to Diaporthe (numbers = score/10)	19
Tolerance to Rhizoctonia (numbers = score/10)	7
Sensitivity to Sclerotinia (numbers = score/10)	40
Size (numbers = score/9)	33
Plant height (cm)	65
Yield (numbers = score/9)	24
Yield (q/ha)	60
Sowing density (seeds m^{-2})	22
Plants/final sq.mt	19
Tolerance to stresses (numbers = score/10)	16
Seedling vigour	7
Level of antinutritional factors	6
1000 seeds weight (g)	73
Protein content (%)	42
Protein content (range)	53
Stalk rating	3
Earliness (numbers = score/9)	9
Suitability to industrial uses	6

Tab. 16 Number of parameters for which information is available per cultivar

Cultivars	Number of parameters	Cultivars	Number of parameters
AIRES	14	MARIANA	
ALBINOS	12	MELI	6
ALISA	5	**MERLIN**	6
ALMA ATA	11	MILOR	3
AMPHOR	9	MITSUKO	
ANITA 66	5	NEOPLANTA	9
ASCASUBI	12	**NIKIR**	14
ASKJA	10	NIKITA	3
ASTAFOR	7	NIKKO	7
ATLANTIC	15	NORMA	3
AVELINE		**OAC ERIN**	9
AVILA	4	OAC VISION	12
BAHIA	7	ORION	4
BALKAN		**ORLANDA**	8
BATIDA	7	OSAKA	3
BLANCA		**PACIFIC**	13
BLANCAS		PAOKI	5
BORNEO	15	**PEDRO**	14
BRILLANTE	12	**PR91B92**	12
CAPNOR		**PR91M10**	15
CASA		**PR92B63**	16
CATALINE		PRIMUS	8
CELIOR	5	PRONTO	6
CLARA	12	PROTEINKA	
COLORADO	13	**PROTINA**	10
CONDOR	14	QUEEN GT 450	5
CRESIR	14	QUITO	6
DEKABIG	12	**REGIR**	14
DEKAFAST	5	**SAFRANA**	11
DEMETRA	13	SAKAI	4
ECUDOR	7	SAKE	4
ESSOR	7	SALTA	3
FASTO	7	SAMURAI	3
FIUME	4	**SANTANA**	9
FLY	3	SAPPORO	8
FORTEZZA	11	SAREMA	4
FUKUI	8	**SEKOÏA**	11
GALLEC	6	**SEPIA**	10
GIULIETTA	13	**SHAMA**	16
GORIZIANA	4	SIGALIA	
HILARIO	14	SOLEDOR	5

IGOR	3	SPLENDOR	3
INDIAN	13	SPONSOR	4
ISIDOR	8	**SUMATRA**	11
KATANA	6	SUPRA	10
KLAXON	14	TAIRA	5
KORADA	10	TEA	12
LANCA	9	TOLIMAN	4
LANDOR	7	TOYAMA	7
LONDON	6	TUNDRA	10
LORY	4	**VANESSA**	
LOTUS	12	VENERA	
MAGNUM	4	ZEN	8
MANUELA	3		

5.4 Summary of growth environmental needs and starting the elaboration of a methodology for crop cultivar selection

To select the four candidate cultivars of soybean with an objective method, an arithmetic formula was ideated to attribute a score to the different cultivars. The formula contains a priority factor attributed to each characteristic, considering that some features are needed while some others are preferred and a few can be disregarded.

Starting from the availability of characteristics for the different soybean cultivars, a priority factor (P) was assigned to each characteristic. This factor is based on the relevance of each feature for the cultivar choice. The highest value (P=3) was assigned to the characteristics indicated in the documents “Proposal for MELiSSA Food Characterisation Phase 1” RFQ NUMBER: RFQ/3-12471/08/NL/JC and “Proposal for MELiSSA Food Characterisation Phase 1 Updates” RFQ/3-12471/08/NL/JC (i.e. group, size, destination, antinutritional factors content, suitability to industrial uses, tolerance to abiotic and biotic stresses) and to the characteristics considered very important, even if not indicated in the document (e.g. yield, protein content). A factor P=2 was assigned to the feature having a medium relevance (e.g. branching, colour of hilum, sensitivity to lodging, stalk rating) and a factor P=1 was attributed to those characteristics less important for the cultivar growth in a closed system (e.g. defoliation, dehiscence, insertion of first pods) (Tab. 17).

Tab. 17 Priority factors (P) and number of cultivars for which information is available

CHARACTERISTICS	**n.CV**	**P**
Destination	30	3
Group	107	3
Level of antinutritional factors	6	3
Protein content	57	3
Sensitivity to Sclerotinia	40	3
Size	78	3
Suitability to industrial uses	6	3
Tolerance to Diaporthe	19	3
Tolerance to Phytophthora	33	3
Tolerance to Rhizoctonia	7	3
Tolerance to stresses	13	3
Yield	70	3
1000 seeds weight	73	3
Branching	11	2
Hilum	30	2
Sensitivity to lodging	84	2
Stalk rating	3	2
Defoliation	19	1
Dehiscence	16	1
Insertion 1st pods	41	1

According to available information reported in the previous paragraphs, each feature is characterised by a different measure unit that is expressed as continuous values or in defined classes, depending on data sources. In order to standardise the values attributed to each parameter, per each feature, also those data expressed with continuous values were summarised into classes. Moreover, considering that the number of classes is not equal per each parameter, the score attributed to different classes was expressed as a percentage factor (X). The highest level of satisfaction corresponds to X=1, while the absence of information corresponds to X=0 (Tab. 18).

Tab. 18 Classes and percentage factors (X) per each feature

CHARACTERISTICS	CLASSES	X
Destination	first crop-first and second crop	1
	second crop	0,5
Group	000 to 00	1
	0 to 0+	0,75
	1- to 1+	0,5
	1/2 to 2	0,25
Level of antinutritional factors	very low	1
	low	0,5
Protein content	very high (>44 %)	1
	high (42-44 %)	0,75
	medium (39.4-41.9 %)	0,5
	low (38,8-39,3 %)	0,25
Sensitivity to Sclerotinia	low	1
	medium	0,66
	high	0,33
Size	low (68-78 cm)	1
	low-medium (79-90 cm)	0,8
	medium (91-102 cm)	0,6
	medium-high (103-114 cm)	0,4
	high (>114 cm)	0,2
Suitability to industrial uses	suitable	1
Tolerance to Diaporthe	high-excellent (score 9-10/10)	1
	medium-good (score 8/10)	0,5
Tolerance to Phytophthora	high-excellent (score 8-9/10)	1
	medium-good	0,5
Tolerance to Rhizoctonia	high	1
	good	0,5
Tolerance to stresses	very high (score 10/10)	1
	high (score 8-9/10)	0,66
	medium (score 7/10)	0,33
Yield	very high (>45 q/ha)	1
	high (score 8-8.5/9; 39-45 q/ha)	0,66

	good (score 7/9; 33-38 q/ha)	0,33
1000 seeds weight	very high (>217 g) high (201-217 g) medium (183-200 g) low (165-182 g) very low (147-164 g)	1 0,8 0,6 0,4 0,2
Branching	high medium-good low-absent	1 0,66 0,33
Hilum	colourless yellow-imperfect yellow fair slightly brown brown	1 0,75 0,75 0,5 0,25
Sensitivity to lodging	very low (7- 18 %) low (19-30 %) medium (31-43 %) high(>43 %)	1 0,75 0,5 0,25
Stalk rating	excellent-strong good	1 0,5
Defoliation	optimal very rapid rapid	1 1 0,5
Dehiscence	resistant (score 10/10) tolerant medium high (score 9/10) medium (7)	1 1 0,66 0,33
Insertion 1st pods	high (15-19 cm) medium (score 6/9 o 13-14 cm) low (11 cm)	1 0,66 0,33

A final score (S) will be calculated per each cultivar, based on the available characteristics, the priority factor and the percentage factor, according to the following formula:

$$S = \Sigma (P_i * X_i)$$

To each cultivar a final score will be assigned to classify them in decreasing order to choose the four showing the highest values.

5.5 Crop cultivar selection

The procedure reported in the previous paragraph is based on the application of an arithmetic formula to attribute a score to the different cultivars. The formula contains a priority factor attributed to each characteristic, considering that some features are needed while some others are preferred and a few can be disregarded.

A final score (S) was calculated per each cultivar, based on the available characteristics (i), the priority factor (P) and the percentage factor (X, partial score assigned to each characteristic), according to the ideated formula.

To each cultivar a final score was assigned to classify them in decreasing order to choose the four showing the highest values.

The cultivars were divided into 5 classes according to the ranking results (Tab. 19). The composition of each class based on the origin of each cultivar (member States) was analysed (Tab. 20). The distribution of the cultivars of each State into the different classes was also considered (Tab. 21)

A summary of the mean values (calculated from data of all cultivars) of the main characteristics for the first four cultivars is reported in Tab. 22. Earliness is expresses as days from harvest and was derived from information about the parameter “group”.

This mathematical ranking approach is intended to be used before the layout of subsequent comparative plant growth test, when quantitative data on available cultivars has become available, to be carried out in either future bench tests in non-sealed controlled environment, or dedicated closed environment chambers.

Tab. 19 Cultivars' classification in classes and according to their final score (S).

CLASS	CULTIVAR	SCORE	n. CHARACTERISTICS
Class 1	**PR91M10**	30,75	15
	SHAMA	24,63	15
	CLARA	24,18	12
	REGIR	23,42	13
	ATLANTIC	23,05	14
	CRESIR	22,37	13
	COLORADO	22,16	12
	PR91B92	20,8	12
	AIRES	20,42	14
	GIULIETTA	20,33	13
	CONDOR	20,3	14
	ALBINOS	20,2	11
	KLAXON	20,12	13
	INDIAN	20,09	12
	PR92B63	19,72	15
	FORTEZZA	19,38	11
	NEOPLANTA	19,29	9
	HILARIO	19,06	13
	NIKIR	18,8	13
Class 2	**BORNEO**	18,51	14
	PEDRO	18,46	13
	LOTUS	17,71	12
	DEMETRA	17,64	13
	PACIFIC	17,36	13
	SUMATRA	17,34	10
	SAFRANA	17,28	10
	PRIMUS	16,92	8
	OAC VISION	16,66	12
	BRILLANTE	16,4	12
	ISIDOR	16,38	8
	ASCASUBI	15,96	12
	LANCA	15,59	9
	ALMA ATA	15,57	10
	KORADA	15,57	9
	SUPRA	15,3	9
	ASKJA	14,93	10

	PROTINA	14,91	9
	TEA	14,12	11
Class 3	NIKKO	13,83	7
	SAPPORO	13,51	8
	FUKUI	13,48	8
	BATIDA	13,47	7
	ORLANDA	13,22	8
	SANTANA	13,01	9
	ZEN	12,72	8
	AMPHOR	12,62	8
	KATANA	12,58	6
	DEKABIG	12,54	11
	TOYAMA	12,3	7
	SEKOÏA	12,24	10
	TUNDRA	11,88	9
	QUITO	11,71	6
	OAC ERIN	11,63	9
	ANITA 66	11,48	5
	SEPIA	11,35	8
	ESSOR	10,79	6
	FASTO	10,76	7
Class 4	SAREMA	10,59	4
	GALLEC	10,29	5
	PAOKI	10,23	5
	ECUDOR	9,91	7
	TAIRA	9,75	5
	LANDOR	9,73	7
	FIUME	9,68	4
	GORIZIANA	9,68	4
	ASTAFOR	9,65	7
	PRONTO	9,61	6
	ALISA	9,53	5
	MELI	9,35	5
	CELIOR	9,21	5
	MAGNUM	9	4
	BAHIA	8,98	7
	TOLIMAN	8,5	4
	LORY	8,48	4
	SPONSOR	7,98	4
Class 5	**LONDON**	7,59	5
	MERLIN	7,59	5

	SAKAI	7,38	4
	AVILA	7,23	3
	DEKAFAST	7,18	5
	SAKE	6,88	4
	ORION	6,7	4
	SAMURAI	6,7	3
	FLY	6,6	3
	NORMA	6,2	3
	SOLEDOR	6,04	5
	IGOR	6	3
	MILOR	5,73	3
	SALTA	5,5	3
	SPLENDOR	5,49	3
	MANUELA	5,45	3
	NIKITA	4,25	3
	OSAKA	4,24	3

Tab. 20 Composition of the classes according to the origin of cultivars

	IT	BG	SK	AT	HU	CZ	DE	RO	total
class 1	94,1	0,0	0,0	0,0	0,0	0,0	0,0	5,9	100,0
class 2	37,0	3,7	14,8	14,8	7,4	7,4	14,8	0,0	100,0
class 3	44,4	0,0	5,6	16,7	16,7	16,7	0,0	0,0	100,0
class 4	68,8	0,0	0,0	12,5	18,8	0,0	0,0	0,0	100,0
class 5	40,9	4,5	4,5	9,1	4,5	0,0	0,0	0,0	63,6

Tab. 21 Cultivars' distribution into the classes per each member Country

	IT	BG	SK	AT	HU	CZ	DE	RO
Total	54	2	6	11	9	5	4	1
class 1	29,6	0,0	0,0	0,0	0,0	0,0	0,0	100,0
class 2	18,5	50,0	66,7	36,4	22,2	40,0	100,0	0,0
class 3	14,8	0,0	16,7	27,3	33,3	60,0	0,0	0,0
class 4	20,4	0,0	0,0	18,2	33,3	0,0	0,0	0,0
class 5	16,7	50,0	16,7	18,2	11,1	0,0	0,0	0,0
	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Tab. 22 Summary of the main characteristics for the first four cultivars

Cultivars	Yield (q/ha)	Height (cm)	Protein content (%)	Earliness
Mean values	42,5	95,2	41,3	108,4
PR91M10	33	81	high	105
CLARA	high	low	40,5	120
REGIR	45,3	90	n.a.	120
ATLANTIC	43,5	90	n.a.	120

(n.a. = not available)

Companies selling the first four cultivars were contacted to check the real availability of seeds to buy and use in the laboratory bench tests. Unfortunately, although they were inserted in the last edition of the Official Journal of the European Union and they were used in the field trials in 2008, some cultivars are not available anymore.
Consequently, we focused our attention on the first 10 cultivars, to evaluate their actual availability. We are contacting several companies to get seeds of these cultivars.
The first 10 cultivars are commercialized by the following companies:

PR91M10	Pioneer
SHAMA	Ragt Semences
CLARA	Panam Seeds
REGIR	Pioneer
ATLANTIC	Venturoli
CRESIR	Pioneer
COLORADO	SIS
PR91B92	Pioneer
AIRES	SIS
GIULIETTA	NK Syngenta

Regarding the cultivar Shama, companies communicated us that it is not sold anymore. At the moment, we have received seeds of the following cultivars: PR91M10, Clara, Regir and Atlantic. These four cultivars will be used in the planned bench tests. Apart from parameters considered for this first cultivar selection, during bench tests also other broad selection criteria will be considered (Tab. 23). Among criteria reported in Tab. 23, the following ones will not be considered: - Volatile organic compound (VOC) production and Root exudate production (no instrumentation available); - Resistance to stress (plants during bench test should be cultivated under optimal conditions and should not be subjected to any stress); - Behavior in extraterrestrial environments (no flight experiments are planned).

Tab. 23 Crop cultivar selection criteria to be considered during bench tests

Requirement s	Criteria	Major parameter(s)	Associated para
Physical - system volume Operational - automation	Crop cultivar stature	Growth space	Handling (harvest)
Performance – food quantity	Crop cultivar target environment	Growth efficiency	Available light leve (energy); CO_2 supplementation
Performance – temporal food availability		Growth period length	Crop senescence
Operational – BLSS interface	Cultivar harvest index	Waste production	Waste degradabilit
Functional – produce crops		Influence of plant growth system	
Performance – food quality	Cultivar nutritional composition	Absence of anti-nutritional compounds	Pro-nutritional com
Performance – food quality	Cultivar edible part composition	Processability	Possible conflict w pro-nutritionals
Performance – food quality		Storage stability	Storage time
Performance – food quality		Palatability	
Performance – food quantity Interface – BLSS	Water use efficiency	Maximum water use Increases growth efficiency	High water turn regeneration rate
Interface – BLSS		atmosphere regeneration capacity	O2 production
Performance – food quantity	Volatile organic compound (VOC) production	Ethylene	Growth inhibition
Performance – food quantity	Root exudate production	Allelochemical inhibiting plant growth	Interspecies compa
Human factor – crew time Operational - automation	Labour requirement	Unlikely to find large difference for this parameter	Monitoring transplanting
Operational – degraded mode	Resistance to stress	Abiotic stress	Recovery from malfunction
Performance – quantity / availability		Biotic stress	System cleanness r
Functional – crop production	Pollination	Self-pollinating cultivar reqs	
Human factor – crew time Physical – system	Propagation	Seed to seed or vegetative	Seed handling/stor
Operational	Behaviour in extraterrestrial conditions	Reduced gravity / reduced pressure	Radiation influenc

5.5.1 *Clarifications regarding the selection method*

In this sub-paragraph some clarifications (notes, N) about characteristics considered in the description of the cultivars and the criteria for the assignment of the percentage factor (X) are reported.

N1) Ranking when data are not available – It was considered that the absence of a datum for a specific characteristic is a negative aspect. Consequently, the assumption of "0" value nullifies the effect of such a characteristic for a specific cultivar and decreases its final score. However, the selection method could be refined during other iterations if needed.

N2) Insertion of the fist pod – This parameter is linked also other aspects such as size, yield and easiness of handling. Since the first two aspects were already considered with specific parameters, the low insertion of the first pod was considered a negative factor for handling easiness.

N3) Destination - It is referred to the period of cultivation (season) and consequently can have impact on the length of the crop cycle and on yield. However, considering that it is generally and mainly linked to the requirements in terms of light, temperature and other factors, higher values were assigned to those cultivars that can be used as both first and second crop.

5.6 References

R. Baldoni, L. Giardini, 1989. Coltivazioni erbacee. Patron Editore, Bologna.

Snidaro M., Signor M., Spolon S., Bellinazzo S., 2006. Le migliori varietà di soia per le semine 2006. *L'Informatore agrario*, 12: 44-48.

Sarti A., Bruno G., 2007. Scelta delle varietà di soia per le prossime semine. *L'Informatore Agrario*, 11: 78-83.

Snidaro M., Signor M., Spolon S., Bellinazzo S., Sarti A., Bruno G., 2008. Varietà di soia alla prova per le semine 2008. *L'Informatore Agrario*, 11: 35-40.

http://www.agriobtentions.fr

http://www.agroservicespa.it

http://www.balcanicooperazione.it

http://www.caussade-semences.com

http://www.cetiom.fr

http://www.diwinetaste.com

http://www.ersa.fvg.it

http://eur-lex.europa.eu

http://www.fao.org

http://www.ifvcns.co.yu/en

http://www.nk.com

http://www.oleosem-semence.asso.fr

http://www.osservatoriobalcani.org

http://www.panam.fr

http://www.pioneer.com/italy

http://www.prograin.qc.ca/accueil.en.html

http://www.ragtsemences.com/rs/siteportail

http://www.sisonweb.com

http://www.soyinfocenter.com

http://www.sisonweb.com

http://www.swissgranum.ch

http://www.terramultimedialeagricoltura.it

http://www.venturolisementi.it

http://en.wikipedia.org

5.7 Appendix 1

Data file: FC1 – TN 98.3.14 - Appendix1 - soybean cultivar tradeoff - 2009.07.16 - UNap.xls

6 General Conclusion

The in this document proposed selection of cultivars is based on a qualitative assessment of cultivar performance data as obtained under field conditions. When available from previous expertise, information from hydroponic cultures was used. Using this preliminary assessment, short-lists of preferred cultivars were proposed for each crop.

A selection method based on a mathematical ranking approach (as summarised in section 5.5), is to be used when quantitative data regarding crop cultivar performance becomes available, obtained from crop growth experiments, run in controlled environments. Such a selection method allows to give priority to key parameters by assigning the appropriate weighing factors, which will determine the ranking of the available cultivars. Such a ranking approach will be used to select the cultivars to be studied in future crop growth tests to be carried out in the PCU infrastructure.