SOLIBAM

Strategies for Organic and Low-input integrated Breeding and Management

Grant agreement number: FP7- KBBE-245058

Collaborative project (Large-scale integrating project)

SEVENTH FRAMEWORK PROGRAMME

Deliverable D4.1

Progress report, summarizing the results of the pre-selection experiments, and describing the wheat (30), clover (3 to 5), maize and bean (15) accessions preselected for potentially improved performance in diversified cropping systems.

Due date: M16

Actual submission date: M30

Project start date: March 1st, 2010 **Duration:** 54 months

Workpackage concerned: 4

Concerned workpackage leader: Paolo Barberi

Dissemination level:

☐ **PU:** Public (must be available on the website)

Abstract

The objectives of this task are:

1. To identify genotypes adapted to diversified cropping systems
2. To assess changes in morpho-physiologal and genetic traits of populations evolving in diversified cropping systems
3. To identify traits that contribute to higher competitive ability
4. To develop methodological contributions to the development of co-breeding
5. To identify particular problems and solutions for on-farm and participatory selection for diversified cropping systems.

While the work of TUM is focused on the basic concepts, i.e. traits conferring higher competitive ability and adaptation of populations, ESAC follows a more practical approach, assessing the potential of co-breeding for the improvement of already established intercropping systems. On the other hand, INRA focuses its investigation on participatory approaches and innovative intercropping systems.

Suitable genotypes could be identified as planned by all three partners involved in the Project, making possible the continuation of the experiments. Due to technical problems, modifications of the experimental programme of INRA were necessary.

Table of content

(1) Activities of INRA (Wheat and clover)

Planned experiments according to the DOW:

***Year 1: 400** accessions of wheat landraces will be grown indifferent environments and at the same time 9 accessions of clover species will be amplified for selecting their attitude to cover crop utilization.*
***Year 2:** selection of 30 accessions and cultivation in small plots with clovers selected for their morphological aspect and frost resistance.*
***Year 3 and 4:** repetition of year 2 activities with a reduced number of wheat and clover populations. The aim is to select 5 wheat populations and 3 clover species.*

Expected outcomes:
INRA will select plant populations bred in association for wheat and will provide a methodological contribution to the development of co-breeding concepts. This part of the project is conducted in a participatory way in the framework of the regional program Pays Blé.

Experiments performed from 2009 to 2011:
Year 1 (2009-2010): A collection of 330 accessions of French wheat landraces ("Blés de Redon") was distributed to 10 farms for reproduction. Each farmer propagated a part of the collection, starting with 100 seeds for each variety.
According to the environmental conditions and the genotype, 50 to 500 grams of each variety were collected. It was however very few, to start an experimentation with.
A collection of 10 species and 32 varieties of legumes (comprising 16 varieties of Black medic, *Medicago lupulina*) was grown for reproduction in 2 farms. Small quantities of seed were collected from all accessions, which, however, was not sufficient for further experimentation.
Decision at the end of the season: as not enough seed were available from the collections of wheat and clover, to perform relevant experiments, the farmers interested in co-breeding built their own experiment with varieties of wheat they are used to (and thus adapted to their place) and with different companion crops.

Year 2 (2010-2011):
The collection of wheat was partly multiplied again (only the varieties identified as interesting by each farmer) and the collection of clover too (only some varieties and by some farmers).
The farmers interested by co-breeding planted their own trials: wheat and *Camelina sativa*, wheat and *phacelia*, wheat and mix of legumes and others. All the trials failed either because they were not sown due to bad weather or due to of unusual weather during the cycle which had bad consequences on the cultivation of wheat or the associated crop.
Since all field experiments failed in 2011/2012, The 30 Wheat genotypes could not be selected, as planned in the DOW. This will be done in 2012/2013, based on the 300

Blés de Redon accessions, which are currently being assessed in an on-farm-trial intercropped with a mix of different legumes.

Year 3 (2011-2012)
2 trials are conducted this year for Task 4.2:
(1) The collection of the 300 “blés de Redon is multiplied completely by co-breeding on-farm in permanent living mulch (a mixture of white clover, *lotus corniculatus* and *Medicago lupulina*). The trial was sown directly into the living mulch canopy without tillage).
(2) A special trial is conducted at INRA, on-station: cultivation of 3 different wheat varieties together with 5 different legumes or alone, so 18 micro-plots and 3 replications.
For the trial (1), the different varieties will be observed globally this year and try to give a note on the behavior of each wheat population together with the legumes (is the wheat giving good production or is it too much competed by the living mulch?).

Trial (2), is heavily affected by weeds but will be evaluated as well, e.g. for competitiveness of the legumes against weeds.

Fig. 1: *Collection of the 330 “blés de Redon” in Co-breeding on-farm (February 2012)*

Fig. 2 *Collection of the 330 “blés de Redon” in Co-breeding on-farm (March 2012)*

Fig. 3 *the INRA co-breeding trial in November 2011 and in February 2012*

Plans for continuation (2012 and after)

Trial (1): a plan will be developed, to continue the experimentation for 2012/2013 together with the involved farmers according their and our ideas. We could for example continue to multiply some of the varieties most interesting in their eyes and maybe also the less interesting ones in order to make comparisons. In 2013/2014, we will then be able to end the project as planned by cultivating the varieties selected in co-breeding with living mulch and as sole crop, in order to observe if there are differences of behavior with and without companion crop.

Trial (2): In order to continue the investigation, this trial will be repeated in 2012/2013. Since the development of the undersown clovers was weak in 2011/2012, both components will be planted earlier in the season, or the legume will be sown before the wheat so that the legumes develop better before the winter (which is possible, because the trials are planted by hand).

(2) Activities of ESAC (Maize and beans)

Planned experiments according to the DOW:

Year 1: *Multiplication of common bean seed stock (100 accessions). During multiplication, some pre-characterization will be done. Based on farmers' empirical knowledge, 15 maize-bean mixtures will be chosen for trials to be performed in 10 locations.*
Year 2: *Multisite trials on bean, based on pre-characterization results, in 10 locations. In parallel, and based on results of year 1, selection of maize and bean for breeding in mixture will be done in two isolations. Year 3: based on results of years 1 and 2, the best five maize-bean combinations (upon their ecological combining ability) will be preserved. In parallel, breeding for mixture in two isolations will continue.*
Year 4: *trials of the best five maize/bean combinations and trials of the breeds obtained in mixture since year 2 will be compared before and after selection: this will be done in 10 locations.*

Expected outcomes:
ESA will select plant populations bred in association for beans and maize, and will provide a methodological contribution to the development of co-breeding concepts.

Material and Methods

2010

Location and germplasm: Intercropping trials were established at two locations in Portugal, Caldeirão and Valada do Ribatejo.
Five intercrops of maize and beans populations were used according to empirical data previously indicated by farmers during a collecting mission (Vaz Patto, et al. 2007). The consociated pairs of maize and beans were respectively

1. Broa 119(32) x 123-4135
2. Broa 57 (17) x 58-4070
3. Broa 70(21) x 73-4085
4. Broa 172(41) x 177-4189
5. Broa 164(39) x 167-4179.

Experimental design: The maize bean pairs were distributed in a complete block design and three reps were used. The field plot was organized in 6 rows, i.e., 4 maize rows (2 per se and 2 near the beans) and 2 bean rows. Each field plot had the following organization: two bean rows, maize intercropped and maize as sole crop. The plot organization made it possible to calculate maize yield as sole crop and intercrop. In case of beans, the data from bean trials at the same location have been used. To reinforce the accuracy, also the data from maize trials at same location have been used.

2011

Two populations, 'SimPre' and 'Pigarro' were selected in a maize-bean intercropping trial composed of: 115-4127, 123-r-4135, 132-R-4144, 137-r-4149, 167-4179, 173-r-4185, 177-r-4189, 191-r-4203, 38-r-4050, 58-r-4070, 73-4085, 85--4097, 167-4179, 177-4189, 73-4085, GC- 45T, GC-17T, GC-22, GC-43, GC-45T, GC-6. Mass selection for beans and maize was done on these two populations.

RESULTS 2010

Fig 4. Maize production (kg/ha) for three systems, in consociation (C), in the same trial but per se (X) and out of the trial but in the same location (M).

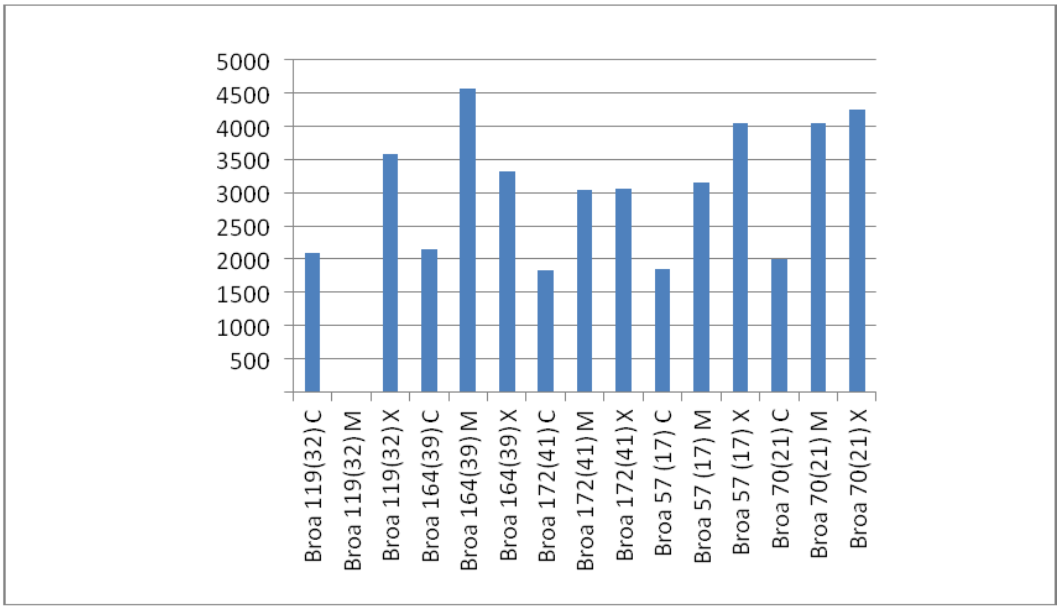
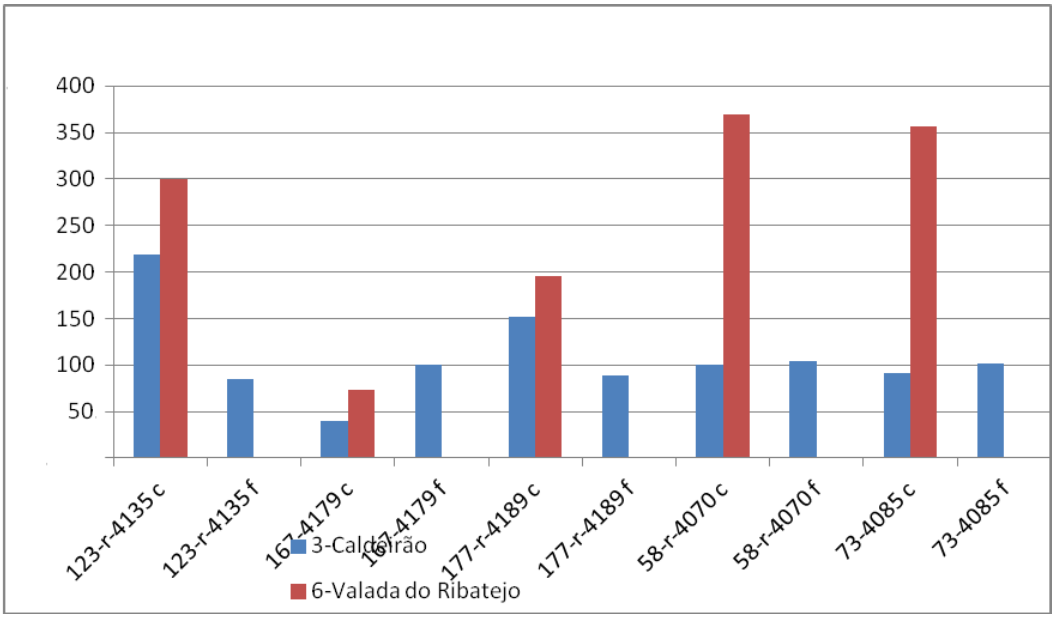


Fig 5. Beans production (kg/ha) for two locations. At Caldeirão location comparison between beans in consociation with maize(c) and *as* sole crops (f).



The yields of the 15 selected Maize varieties are represented in Figure 4.
Yields of Broa 172(41) x 177-4189 and Broa 57 (17) x 58-4070 were significantly lower than the other populations both in consociation or not (1824.67 and 1845.26 respectively) and the maximum yield of consociation was obtained in Broa 164(39) x 167-4179 (2141.14 kg), being the 2^{nd} ranked population at Valada do Ribatejo but the 4^{th} at Caldeirão. The Broa 119(32) x 123-4135 was the first at Valada but the lost at Caldeirão.
When populations were considered per se in the consociation trial Broa 57 (17) and Broa 70(21) were the highest in yield (4048.235, 4241.458). Hence in another trial the highest in yield were Broa 70 and Broa 164 (4052.82, 4574.99 respectively)

The 123-r-4135 and 177-r-4189 were the accessions that yielded more simultaneously in both locations and 58-r-4070 was the high yielding for Valada do Ribatejo.
The comparison between consociated versus non consociated beans indicate that non-significant differences were obtained. Nevertheless 123-r-4135 and 177-r-4189 were better in consociation than *per se* (219.26 versus 84.96 kg/ha and 152.16 versus 88.69 kg/ha).
The Broa 119(32) x 123-4135 was the better combination when the mean yield product from maize and beans was ranked. In addition this consociation was the better for both locations tested.
The Broa 70(21) x 73-4085 was 3^{rd} rank in both location and for maize and beans yield. The Broa 164(39) x 167-4179 consociation was the best for maize (2141.13 kg/ha) but the worst for the beans (56.52 kg/ha).

(3) Activities of TUM (Wheat and subterranean clover)

Description of the experiments, according to the DOW:
Experiment 1** (Evolution experiment)**: *A wheat Composite Cross Population (CCP) will be grown over three consecutive years in a subterranean clover living mulch and as sole crop. The experiment will be performed in different environments (at least one in a Mediterranean environment, and one in Central and Northern Europe). The composite cross should already be adapted to the respective environmental conditions but should have the same origin. Every year, a part of the harvest will be stored to permit comparison of the generation in the fourth year, when changes in the population structure will be investigated at morphological, physiological or molecular level, in cooperation with WP1 and WP3.*

***Experiment 2** (split plot experiment):* *400 single spikes selected from a Wheat CCP will be planted separately in narrowly-spaced rows. 150-200 well adapted but morphologically diverging lines will be selected and harvested separately for the assessments to be made in the subsequent years. Year 2: screening of 200 preselected lines in small unreplicated split plots, with or without living mulch. Year 3 and 4: repetition of the screening in the first year, but with a restricted number of selected lines.*

Expected outcomes
Aim of the experiments is

- To find out whether selection for aptitude to living mulch systems is necessary or advantageous in wheat
- to identify traits specific for competitive ability in wheat-subterranean clover living mulches,
- to identify critical periods, determining the balance between main crop and ground cover and
- To find out, whether competition in early or in later development stages is more important.

Our main hypotheses were, that early growth vigor is the most crucial factor, that a competitive disadvantage acquired in early growth stages may difficultly be compensated in later stages, and that the „classical“ traits described as determining competitiveness, like plant height or leaf habit are only of secondary importance.

Experiments performed, 2009-2012

Exp. 1: Evolution experiment
The CCP used was the „YQ-CCP“generated by ORC, adapted to the conditions of southern Britain. Plots of 10 x10 m, with and without undersown subterranean clover (cv. „Campeda“) were planted in three environments in 2010 and 2012. The field experiments were located near Freising (Germany), Pisa (Italy) and Newbury (UK). The seeding dates were mid-September (Germany) and Mid October (UK). At Pisa, due to exceptional rainfall, the plots could not be established as planned in October

2010. It was attempted to plant the trial in February, 2011, but the attempt failed, because the wheat was not vernalized. In all locations, the wheat CCP was drilled at usual density and row distance and the subterranean clover was seeded broadcast, at a density of 40 kg/ha. Wheat and Subterranean clover were planted contemporarily at Freising and Pisa; at Newbury, the subterranean clover was undersown into the wheat stand in the second half of October. In the latter case, the sub clover did not develop well and was suppressed by wheat; consequently it was decided to plant both species together and earlier in 2011/2012. At Freising, both clover and wheat developed well. In 2011/2012, instead of Pisa, the plots were planted at the experiment station of the „Universita' Della Tuscia"of Viterbo (Italy) in the mid of October. The trials at Freising and Newbury were planted in the mid and the end of September. All trials developed satisfactorily.

Exp. 2 Split plot experiment

The split plot experiment is based on the same CCP as Exp. 1.

400 Ear-rows were selected in the UK in planted in 2009 at TUMs organic experiment farm in Viehhausen near Freising. 200 lines, apparently adapted to the local environmental conditions but diverging in morphological and phenological characters, were selected in 2011 and planted in split plots (4x2m each) without replication at Dürnast Experiment Farm of TUM (Germany) in the mid of September. Half of the split plots was undersown with subterranean clover. The following assessments were made (or are currently being made by digital image analysis): (1) Ground cover, both by legumes and wheat by digital image analysis, repeatedly until EC 32. (2) Plant height, both of wheat and clover as well as leaf habit, at EC 32 and 65. (4) Grain yield with and without the competition by the subclover living mulch (5) number of culms/m².

In 2011, 125 genotypes were tested in a partially replicated plot experiment; as in the precedent year in split plots, with and without undersown subterranean clover. 5 commercial varieties and the composite cross population from Exp. 1 (both evolved with and without competition by subclover living mulch) were included in the experiment. 25 genotypes were planted in 4 replications. The size of a sub-plot was 4x2 m. The assessments will be the same as in the precedent year.

Results

From Exp. 1 the first results can be expected only after the first evaluation, i.e. in 2014.

Also Exp. 2 needs several years for a full evaluation. The first evaluations of the results of 2010/2011 are still in course, but some preliminary results may already be summarized:

(1) In almost all plots, the consociated clover reduced grain yield, in average by 30 % (fig. 6). This yield reduction was particularly high, because, in order to create a high competition pressure, the clover was seeded broadcast at relatively high density

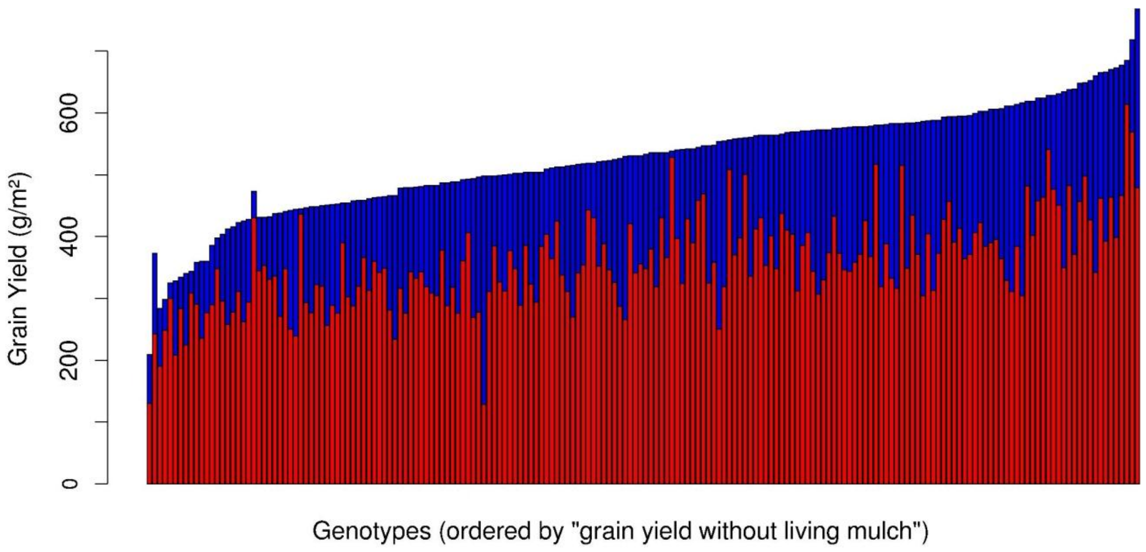
(higher than typical for LM systems, e.g. in our agronomic trials). The yield reduction affected both the number of spikes/m² and the single spike yield.

(2) Considerable differences in yield reduction among single genotypes could be observed (fig. 6). Since these are only the results of the first year, and still in unreplicated plots, it cannot be decided yet with certainty, if the population contains genotypes with particular aptitude to grow in living mulches. However, since there was a significant correlation with morphologic characteristics, e.g. plant height, it is to be expected that such differences will be revealed, when results over several years, and with replications are available.

(3) The preliminary analysis shows, that growth vigor in the earlier development stages (i.e. during tillering), resulting in higher degrees of ground cover, were correlated negatively with yield reduction in competition with subclover living mulch, while this could not be shown for plant height (measured at EC 32 and 65). However, in our population, grain yield (with and without living mulch), ground cover during tillering, plant height at the end of tillering and at maturity were correlated, and thus, plants with fast early development, high biomass production and tall plants were among the best performing, with living mulch and without, though their yield reduction.

This supports our hypothesis, that competition traits in early development stages (especially growth vigor) are more crucial, compared to morphological traits like plant height or leaf habit. Disadvantages acquired before canopy closure could difficultly be compensated later.

Fig. 6: Grain yields of the genotypes tested in Exp. 2 in 2010/2011, without and with (red) living mulch.



Plans for continuation: Both trials will be continued as planned. Since the trial of the first year of the evolution experiment failed in the Italian and British location, it would be better, to perform the evaluation trial in 2014/2015 instead of 2013/2014, which would be beyond the duration of SOLIBAM. However, TUM intends to continue the evolution experiment for several years and to perform another evaluation trial.

(4) Summary and future prospective

Based on the first results and observations, we can suppose, that genotypes with particular aptitude to intercropping can be found in both the gene pools used by TUM and ESAC. The experimentation in the following years will reveal, if appropriate testing procedures are necessary, or if selecting particular ideotypes (e.g. high-biomass genotypes with rapid youth development), which can be identified also without special testing procedures), is sufficient. In connection with the experiments performed in the frame of task 4.2, it will also be possible, to evaluate the respective role of the main crop genotypes and that of management practices for the control of competition.

The results of the first Years of the on-farm and participatory experimentation of INRA show, that participatory breeding in innovative intercropping systems is much more challenging than simple selection as sole crops, especially if both living mulch systems and plant breeding are new to the involved farmers. In this case, more technical assistance is necessary, on station testing might be included and, if possible, farmers with experience with innovative cropping systems should been chosen. All these aspects will be considered in the experiments planned for the next years.