Résumé

Utilisation des ressources génétiques locales de *Vicia faba* L. pour le développement de variétés: amélioration des populations

M. SADIKI

L'amélioration des populations sources à travers les systèmes de sélection récurrente facilite l'exploitation du germplasm local en création variétale. L'objectif de cette étude consiste à évaluer la réponse à 3 cycles de sélection récurrente, sur demi-frères, pour les composantes du rendement chez la fève. Ainsi, 12 populations de familles de demi-frères ont été dérivées par sélection en présence et en l'absence de *Botrytis* dans deux environnements. Ces populations et la population mère ont été plantées selon un plan en blocs aléatoires complets à 3 répétitions à la station expérimentale de l'IAV Hassan II, Tadla. Les caractères étudiés sont le nombre de gousses par plante, le nombre de graines par gousse et le poids moyen d'une graine. Les analyses ont montré qu'à chaque cycle, les moyennes des quatre "pools" sont différentes pour tous les caractères. De même, à chaque cycle, les 4 "pools" sont significativement supérieurs à la population source indiquant un progrès positif à chacun des cycles de sélection. La variabilité intra-population est réduite dans le dernier cycle de sélection par rapport à la population d'origine.

Mots clés: *Vicia faba* L. - Amélioration des plantes - Sélection récurrente - Variabilité - Progrès génétique

Summary

Exploitation of local populations of *Vicia faba* L.for variety development *Vicia faba* L. : germplasm enhancement

M. SADIKI

Germplasm enhancement through recurrent selection systems facilitates the exploitation of local populations for variety development. The objective of this study is to evaluate the response to three cycles of half sib based recurrent selection for Faba bean yield components. Thus, 12 populations of half sib families were derived by selecting in a Moroccan gene pool under 4 conditions: under inoculation and in the absence of inoculation of *Botrytis* across 2 locations. These sub populations and their parental population were grown in a randomised complete block design with 3 replications at Tadla Experimental station, IAV Hassan II. The traits measured included the number of pods per plant, the number of seed per pod and the seed weight. The analyses at each cycle showed that the 4 populations were significantly different for each trait. The mean of the 4 subpopulations were significantly different for higher than the mean of the parental population indicating a significant selection progress. Compared to the original gene pool, the intravariation in the subpopulations of the third cycle was narrower.

Key words: *Vicia faba* L. - Plant breeding - Recurrent selection - Variability - Genetic progress

BREEDING HETEROTIC FABA BEAN VARIETIES WITH RESTRICTED EXPENSE

W. LINK*

1. INTRODUCTION

Knowledge of the reproductive mode of a crop is crucial to develop a breeding scheme. Faba bean is both, self-fertilising and cross-fertilising, the degree of cross-fertilisation of Central European lines is on average 50% (Link *et al.*, 1994). The reproductive mode in Mediterranean materials seems to be similar (DePace & Vittori 1993), but further research is needed to clarify the situation. Heterogeneity and heterosis markedly increases both level and stability of yield (Link *et al.* 1994, Stelling *et al.* 1994a, Stelling *et al.* 1994b). Hence, the productivity of open pollinated populations is greater and more stable than of inbred lines bred from them. For Central European material it was shown that populations, if established as synthetic cultivars, clearly outyield the highest yielding of their inbred components (Link *et al.*, 1994).

Plant breeding activities can be separated in a short-term and a long-term part:
- extraction of superior experimental cultivars from base material;
- improvement of this base material, i.e., population improvement.

In the following, for both parts a methodical proposal is given, and special attention is paid to the specific reproductive mode of faba bean and to a low expenditure needed for their realisation. The proposals result from research on faba bean at the Universities Hohenheim and Göttingen in the years 1984-1994 (Cf. Link *et al.*, 1994; Stelling *et al.*, 1994b).

2. BREEDING SYNTHETIC CULTIVARS

Synthetic cultivars are superior to line cultivars in two aspects: they give a more stable yield and a higher yield.

An improvement in yield stability is realised in most cases, since a synthetic is a mixture of genotypes. Genotype x environment interactions are mostly present, and are more marked for any single genotype (line cultivar) than for mixtures (synthetics).

* Georg-August University Göttingen, Institute of Agronomy and Plant Breeding, D - 37075 Göttingen

An improvement in yield performance (and a further improvement in stability) mainly depends on the degree of cross-fertilisation between single plants within the synthetic cultivar.

A synthetic faba bean cultivar should be bred from 4 to 8 components. To make reasonable use of the additive genetic variance in the selection, these components should be homozygous inbred lines (or nearly so, the last ancestral single plant should at least be in generation F4). The components are mixed in equal proportions and grown in the open field (access of honey and bumble bees) with an appropriate distance from other faba bean crops. This generation represents the Syn-0. Its yield represents the next generation, Syn-1, which is again grown in the open field with an appropriate distance from other faba bean crops. The next generations, Syn-2 and Syn-3, should be grown in the farmer's field. The farmer can multiply this seed on-farm for several (theoretically for an unlimited number of) generations without risking loss of genetic potential of his crop. Throughout, and especially one generation before the use in the farmer's field, optimum conditions should be created for high outcrossing within the synthetic (e.g., placement of honey bees).

The crucial step in breeding a synthetic cultivar is the selection of the appropriate components which will give rise to the Syn-0. On which kind of information, gathered from which kind of entries in the field test, shall the selection be based ?

Two arguments may be mentioned against the evaluation of the components (i.e., inbred lines) per se in field tests (i.e., disfavouring the use of seed from isolation cages for field test plots):

- To allow selection, a high number of inbred lines have to be developed and maintained in isolation cages (to avoid fertilisation with other than self-pollen). This can be done, but it will be costly as soon as a high (e.g., >10) number of plants per line have to be handled. A higher number (>40, to allow for the production of enough seed) would indeed be necessary, if the lines' per se performance would have to be tested in multilocal field trials.
- The correlation coefficient between the per se performance of a line and its varietal ability (usefulness as component in a synthetic cultivar) is high for most traits, but is low for yield.

Two arguments can be mentioned in favour of the evaluation of the components via their polycross-progenies in the field test :

- The polycross is a step of seed multiplication that is markedly less expensive than a multiplication in isolation cages. Hence, use of seed from a polycross, i.e., polycross-progenies, for field testing an inbred line is economically superior to use of seed from a purely self-fertilised progeny (i.e., seed from isolation cages).

- The correlation between the performance of a line's polycross-progeny with its varietal ability is high for most traits, and is still medium to high for yield. The entries of a genuine polycross are single plants. To reduce the expenditure of the polycross (sowing, harvesting), here a modified polycross is proposed, i.e., to sow small groups of e.g. 3 plants of the components (lines) as entries (the seeds sown in the polycross have of course to be produced in isolation cages). These groups have to be replicated, the number of replicates depending on the amount of seed that needs to be produced for the field test. Randomisation must be used, to give every component as far as possible the same probability to be pollinated with every other components' pollen.

If the specific reproductive mode of the faba bean is thoroughly taken into consideration (Link & Ederer 1993), it becomes clear that the correlation between the performance of a line's polycross-progeny and its varietal ability should be higher, if the progeny is produced via a modified polycross than if produced via a genuine single-plant polycross.

3. A RECURRENT SCHEME OF POPULATION IMPROVEMENT

This scheme was developed to allow effective population improvement without isolation cages, hand-crossing, hand-tripping, i.e., without full control of the pedigree. A further restriction was that field tests should be multilocal and yearly, without the need of establishing a second season per year.

Yearly field tests are a necessity in faba bean, because improvement of yield stability is a major objective.

Table 1 refers to the specific reproductive mode of the bean. It is further assumed that the degree of fertilisation with unrelated "cross-pollen" is constant (it is $[1 - s]$; s = degree of self-fertilisation, $0 < s < 1$), i.e., disregarding whether plants were grown singly or related plants were grown in rows. It is furthermore assumed that the population is in genetic equilibrium, i.e., many generations of open pollination already occurred, selection, mutation, migration, and drift being absent. Then, the progeny of every single plant consists of two fractions: the first is its selfed progeny (i.e., S1-line), the second is the randomly outcrossed progeny, i.e., it represents a half-sib family (having many random male parents and the ancestral single plant as common female parent). The progeny of this progeny then consists of four fractions as shown in Table 1.

In case of 50 % self-fertilisation and 50% cross-fertilisation (i.e., $s = 0.5$), after two generations of successive open pollination about 9/16 of the genes are still originating from the common ancestral single plant.

Table 1. Additive variance between (ancestral) single plants and between their progenies produced by one and two generations of open pollination (once and twice open pollinated progeny, respectively) for a partially allogamous population in equilibrium[a] with a degree of self-fertilisation of s (0<s<1)

	Content of genes originating from ancestral single plant: General	Content of genes originating from ancestral single plant: s=0.5	Amount of additive variance (*) between entries: General	Amount of additive variance (*) between entries: s=0.5
Ancestral single plant	1	1	$\frac{2}{(2-s)}$	1.33
Once open pollinated progeny: (s) S_1-line; (1-s) Half-sib-progeny	$\frac{(1+s)}{2}$	$\frac{3}{4}$	$\left[\frac{(1+s)}{2}\right]^2\left[\frac{2}{(2-s)}\right]$	0.75
Twice open pollinated progeny: (s) S_2-bulk, S_1-family; (1-s) Half-sib-family, S_0-family	$\left[\frac{(1+s)}{2}\right]^2$	$\frac{9}{16}$	$\left[\frac{(1+s)}{2}\right]^4\left[\frac{2}{(2-s)}\right]$	0.42

[a] F_e = equilibrium inbreeding coefficient = $\frac{s}{(2-s)}$ $^{*}=\sigma_A^2$

This result might be compared with a classical half-sib family, which contains only 1/2 of the genes of the ancestral (in this case: mother) plant. The amount of additive genetic variance that can be used when selecting among the twice open pollinated progeny is given as well. It is higher than the 1/4 σ^2 that can be used when selecting among classical half-sib progenies. In the following recurrent selection scheme, selection among this kind of twice open pollinated progenies is proposed.

As indicated in Figure 1, the procedure consists of three parts that are grown yearly and simultaneously: (i) a polycross, (ii) a multiplication plot and (iii) field tests. Numbers are given as examples and may be modified.

The purpose of the polycross is to induce cross-fertilisation among the entries of the polycross (i.e., recombination). Any means that increase cross-fertilisation should be used (placement of honey-bees etc.). Any means that increase the productivity and health of the plants should be used (low plant density, seed-treatment, hand-hoeing, hand-weeding, fertiliser (P, K), Orobanche-free plot, irrigation, pesticides, etc.).

Nine seeds harvested from one single plant in the last cycle's polycross are grown in short rows of 3 seeds per row and 3 randomised replicates. Just prior to anthesis, the number of plants is reduced to two per row (to reduce mating of related plants). Only one plant per replicate will be harvested (sowing three plants though only one has to be harvested is proposed to minimise the probability of failure). The harvested plant should yield at least 39 healthy seeds to allow the establishment of the next cycle (9 for the next polycross, 30 for the next multiplication plot).

The purpose of the multiplication plot is to produce seed for field test. No attempt should be made to increase outcrossing. Any means that increase the productivity and health of the plants should be used (low plant density, seed- treatment, hand-hoeing, hand-weeding, fertiliser (P, K), Orobanche-free plot, irrigation, pesticides, etc.).

Thirty seeds harvested from one single plant in the last cycle's polycross are grown in one two-row plot. From this plot, at least 30 x 40 = 1200 seeds should be harvested. This allows field testing in a total of approx. 30 m^2 of field plot area, e.g., at three locations with two replicates each and a plot size of 5 m^2. The field tests should be carried out as usual.

Hence, a single plant harvested in one replicate of the polycross in cycle n gives rise to 3 single plants in the polycross of cycle **n+1** and to 1 multiplication plot (once open pollinated progeny) in cycle **n+1**. A multiplication plot of cycle **n+1** gives rise to 1 field test entry (twice open pollinated progeny) in cycle **n+2**.

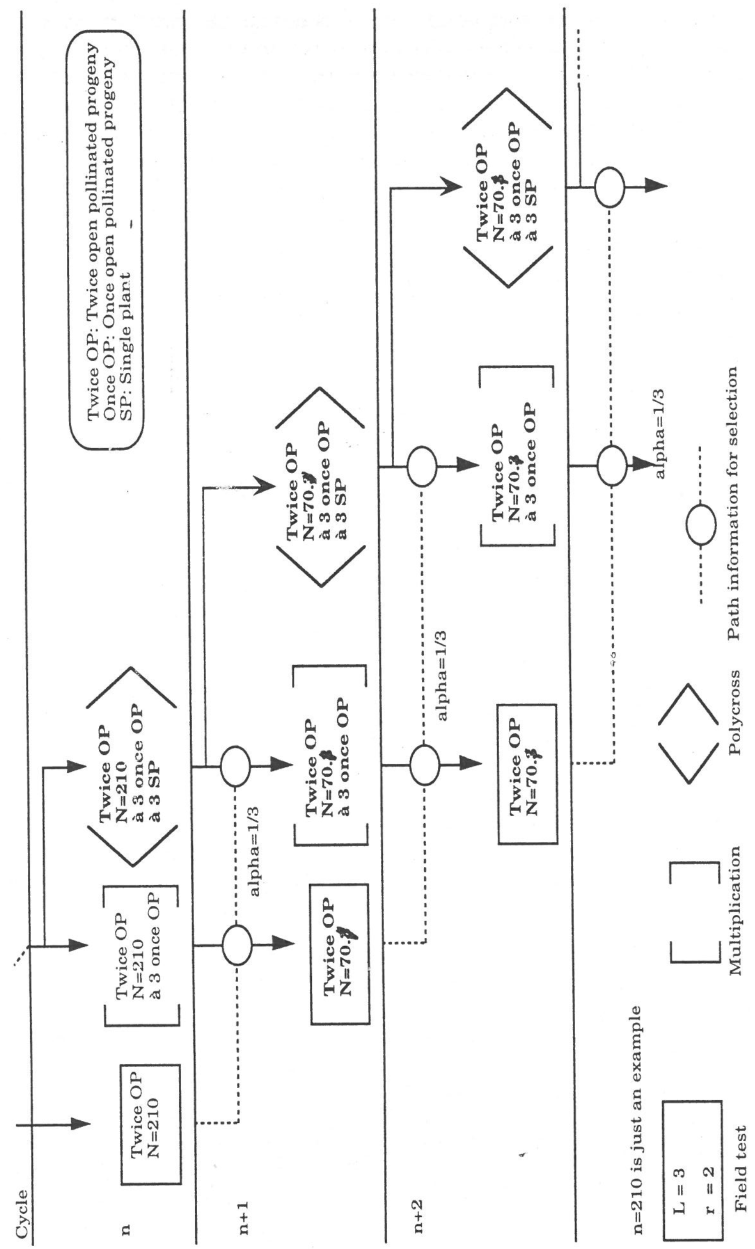

Figure 1. Recurrent selection in *Vicia faba*

The pedigree relationship of those 9 single plants of the polycross and those 3 entries of the multiplication plot, that are commonly represented by 1 member in the field test, and that all trace back to a common ancestral single parent (two cycles earlier) must be thoroughly recorded.

Selection is made according to the results of the multicolal field test. The top third of the field entries (twice open pollinated progenies) are selected (hence, the overall size of the program is kept constant). The seed harvested from those multiplication plot entries that (in groups of 3) originate from the by now selected ancestral single plants, will be used to establish the field test of the next cycle. The seed harvested from those polycross plants that (in groups of 9) trace back to the, by now selected ancestral single plants, will be used to establish the polycross and the multiplication plot for the next cycle. Hence, the origin of the information for selection is only the field test, and selection is only between twice open pollinated progenies that trace back to a common ancestral single plant, not within them.

New, promising genotypes may enter this population improvement program. They will enter via the polycross. To not enlarge the program, selection could be stricter in this case (< 1/3).

The yearly field test is an important feature of this scheme. This is made possible in spite of the two seasons that are needed from the ancestral single plant to the twice open pollinated progeny (which is grown in field tests). The solution that was proposed herewith was the production of recombined and multiplied progenies in anticipation, one and two seasons before needed. Only 1/3 of the entries of the multiplication plot and only 1/9 of the entries of the polycross will ultimately be represented in the field test. This nevertheless is no substantial waste of effort, since they are grown in the open field with very low expenditure (no isolation, no tripping etc.).

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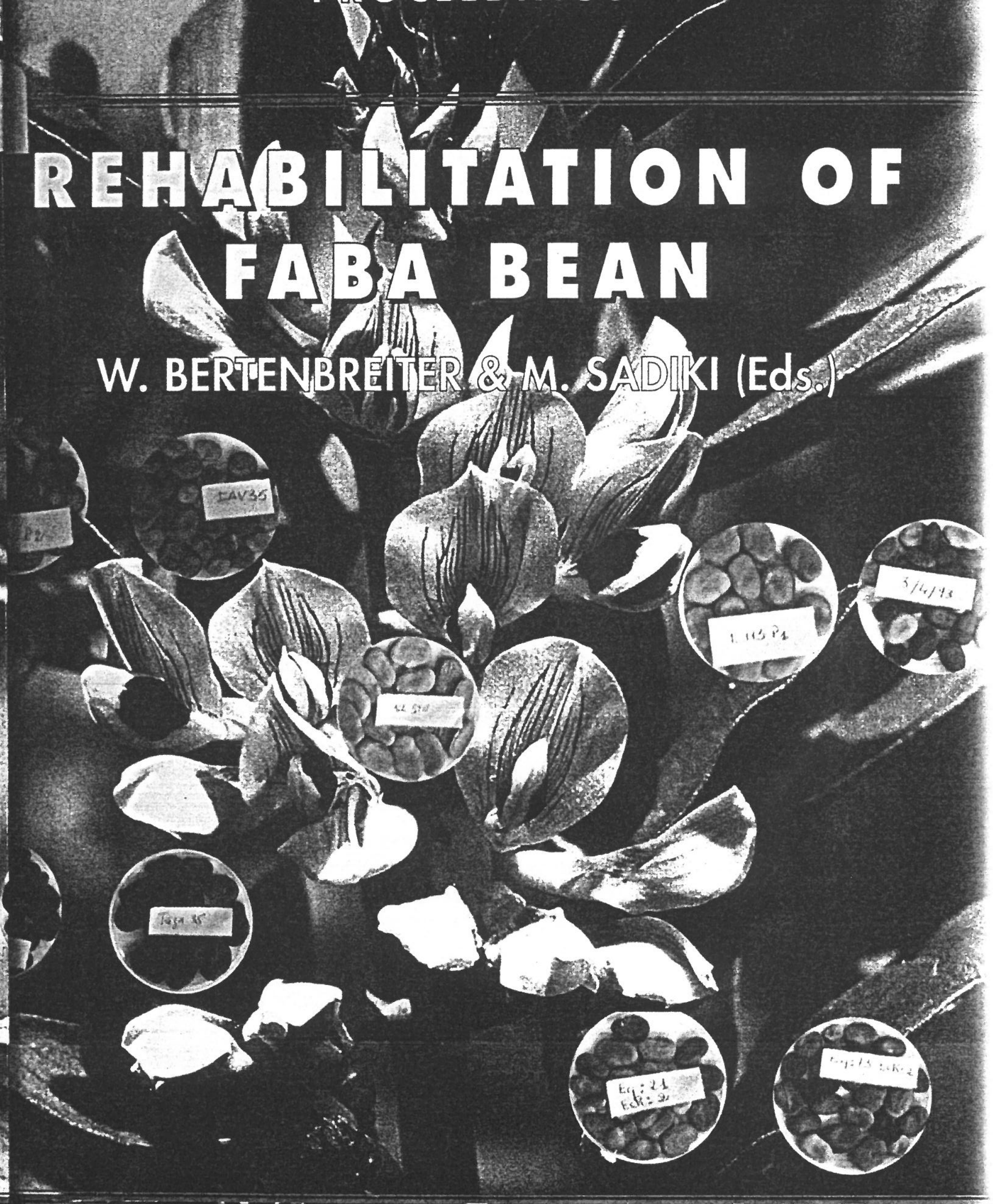

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