Danke sehr für die Einladung nach Gatersleben ☺

September 12, 2024. Vavilov-Seminar, IPK Gatersleben.

“Breeding faba bean, a task like taming of a recalcitrant Diva”; Wolfgang Link.

Includes findings of W. Ederer, L. Ghaouti, L. Brünjes, A. Windhorst, H. Laugel.

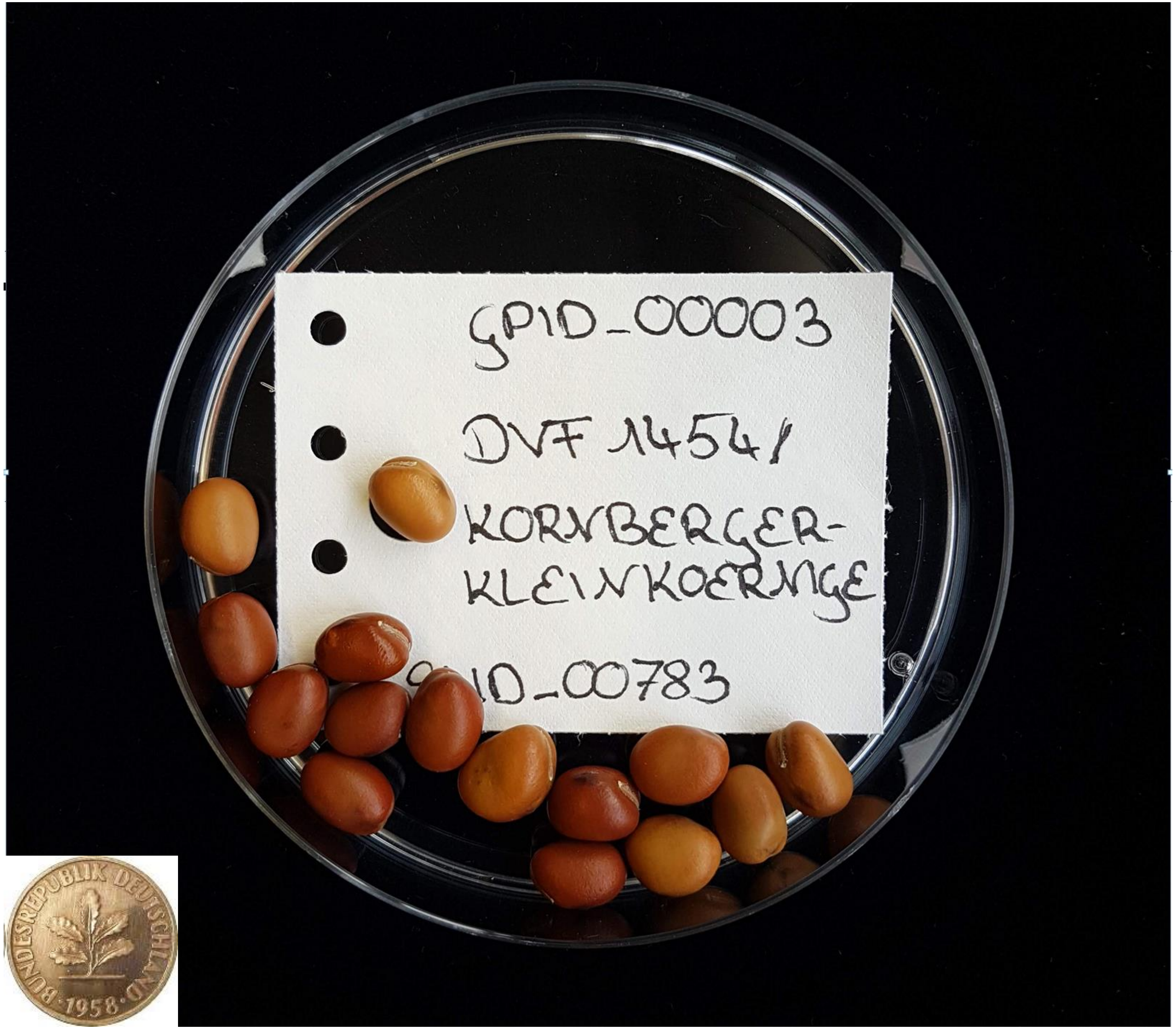
Grain legumes. Pulses. *Körner-Leguminosen*

www.syngenta.ch/renaissance-der-huelsenfruechte

- Pea (*Erbse*; *Pisum sativum*)
- Soy (*Sojabohne*; *Glycine max*)
- Lupin (*Lupine*; *L. angustifolius*, *L. albus*, *L. luteus*)
- Kidney bean (*Gartenbohne; Phaseolus vulgaris*)
- Chickpea (*Kichererbse*; *Cicer arietinum)*
- Lentil (*Linse*; *Lens culinaris*)
- Mungbean (*Mungbohne*; *Vigna radiata, V. mungo*)
- Black-eyed bean (*Augenbohne, V. unguiculata*)
- …
- Runner bean (*Feuerbohne*; *Phaseolus coccineus*)
- Pigeon pea (*Straucherbse*; *Cajanus cajan*)
- …
- Faba bean (*Ackerbohne*; *Vicia faba*)
- ..

Ackerbohne
Pferdebohne
Saubohne
Puffbohne
Feldbohne
Faba bean
Tick bean
Field bean
Broad bean
Fève
Féverole

Vicia faba:
-paucijuga
-minor
-equina
-major

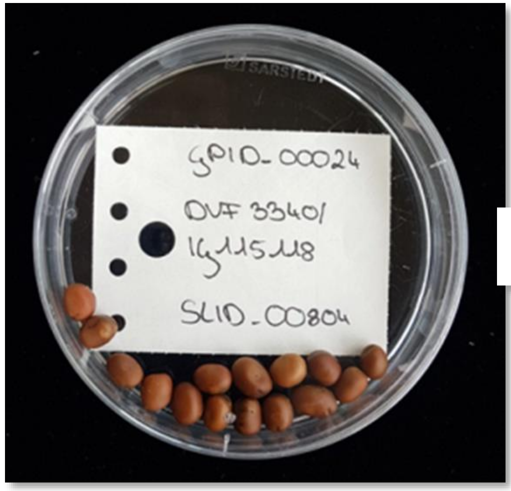


Vicia faba minor
~~300g < TSW < ~~600

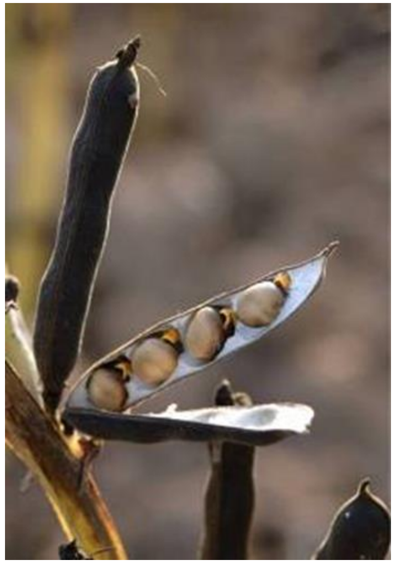
Vicia faba major
~~800g < TSW < ~~2500g


GPID_00002
DVF 1343/
PI221517
SLID_00782
GPID_00030
DVF 3354/
IG124115
GPID_00193
GPID_00083
ACEQUIA
GPID_00024
DVF 3340/
IG115118
SLID_00804
GPID_00003
DVF 1454/
KORNBERGER-
KLEINKOERNIGE
GPID_00103
ILB 6584
GPID_00042
DVF 1736

Vicia faba minor vs. *Vicia faba major*.
A strange coincidence of extremes in the yield components ‘seed size’ and ‘number of seeds per pod’.



Small-seeded types since >10.000 years



Large-seeded types since ~1.200 years

Before 1980:
Breeding Germplasm
North of Alpes and Pyrenees:

Minor
(e.g. cvs. Herz Freya,
Maris Bead)
1 tiller per plant
Late (flowering, maturing)
Tall; asynchronous ripening; low harvest index.

Major
(e.g. cvs. Con Amore,
Minica)
2-4 tillers per plant
Early (flowering, maturity)
short; synchronous ripening; high harvest index.

Origin of *Vicia faba*: Mesopotamia (Iraq) and/or Levante (Near East; Arabia, Palestine)
Vicia faba minor in NW Europe 2-3 thousand of years before *major* evolved;
Vicia faba major from ~800 A.D.; probably from Mesopotamia.

eLIBRARY ID: 22768022 EDN: RGKQOJ

2014

THE LOST ANCESTOR OF THE BROAD BEAN (VICIA FABA L.) AND THE ORIGIN OF PLANT CULTIVATION IN THE NEAR EAST

KOSTERIN O.E.[1,2]

[1] Institute of Cytology and Genetics SB RAS
[2] Novosibirsk State University

SCIENTIFIC REPORTS

OPEN

14,000-year-old seeds indicate the Levantine origin of the lost progenitor of faba bean

Received: 13 June 2016
Accepted: 27 October 2016

Valentina Caracuta[1,2], Mina Weinstein-Evron[3], Daniel Kaufman[3], Reuven Yeshurun[3], Jeremie Silvent[4,†] & Elisabetta Boaretto[1,2]

From archaeological excavations

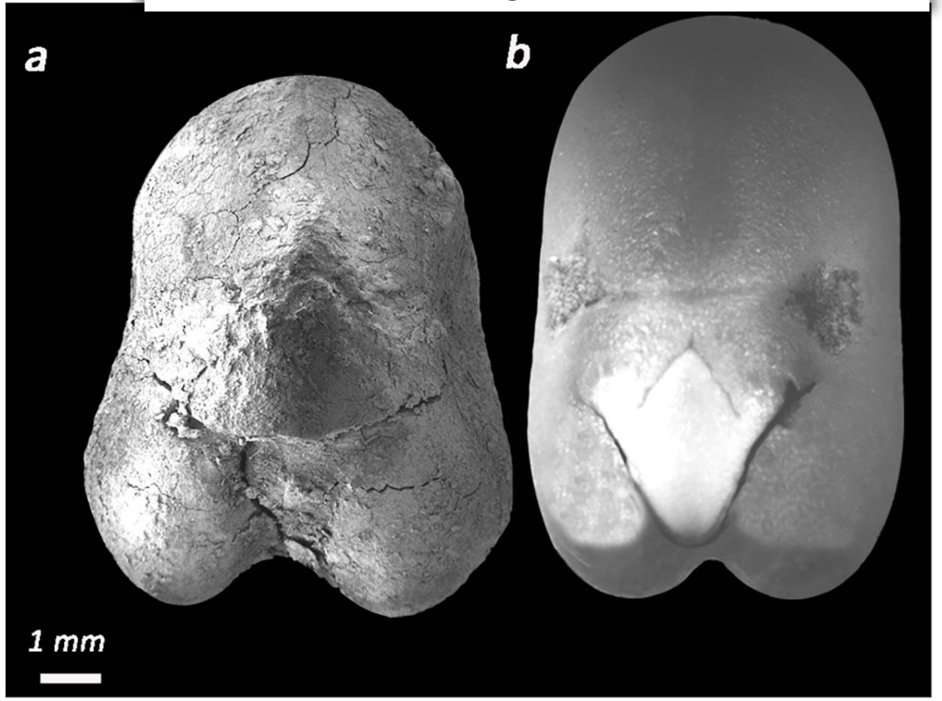


Fig 5. ***Vicia faba.*** (a) specimen from L 450; (b) modern faba bean.

https://doi.org/10.1371/journal.pone.0177859.g005

Faba bean. An Old-World Bean.

Beans in our fairy tales are – of course – neither *Phaseolus nor Vigna*, but *Vicia*.
'Our' beans are vetches ;-)

Göttinger Tageblatt

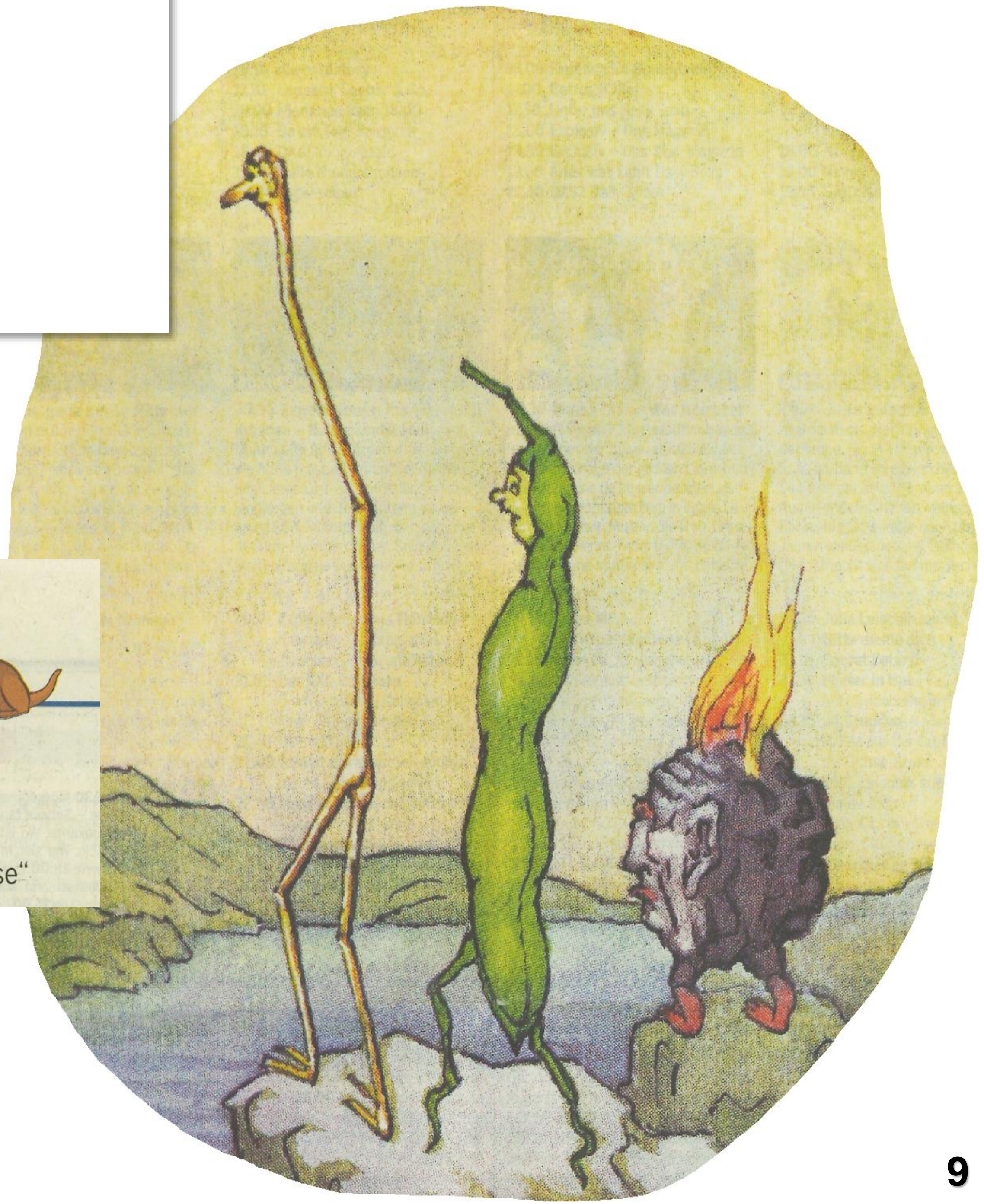

MITTWOCH, 3. JULI 2013

KINDERSEITE

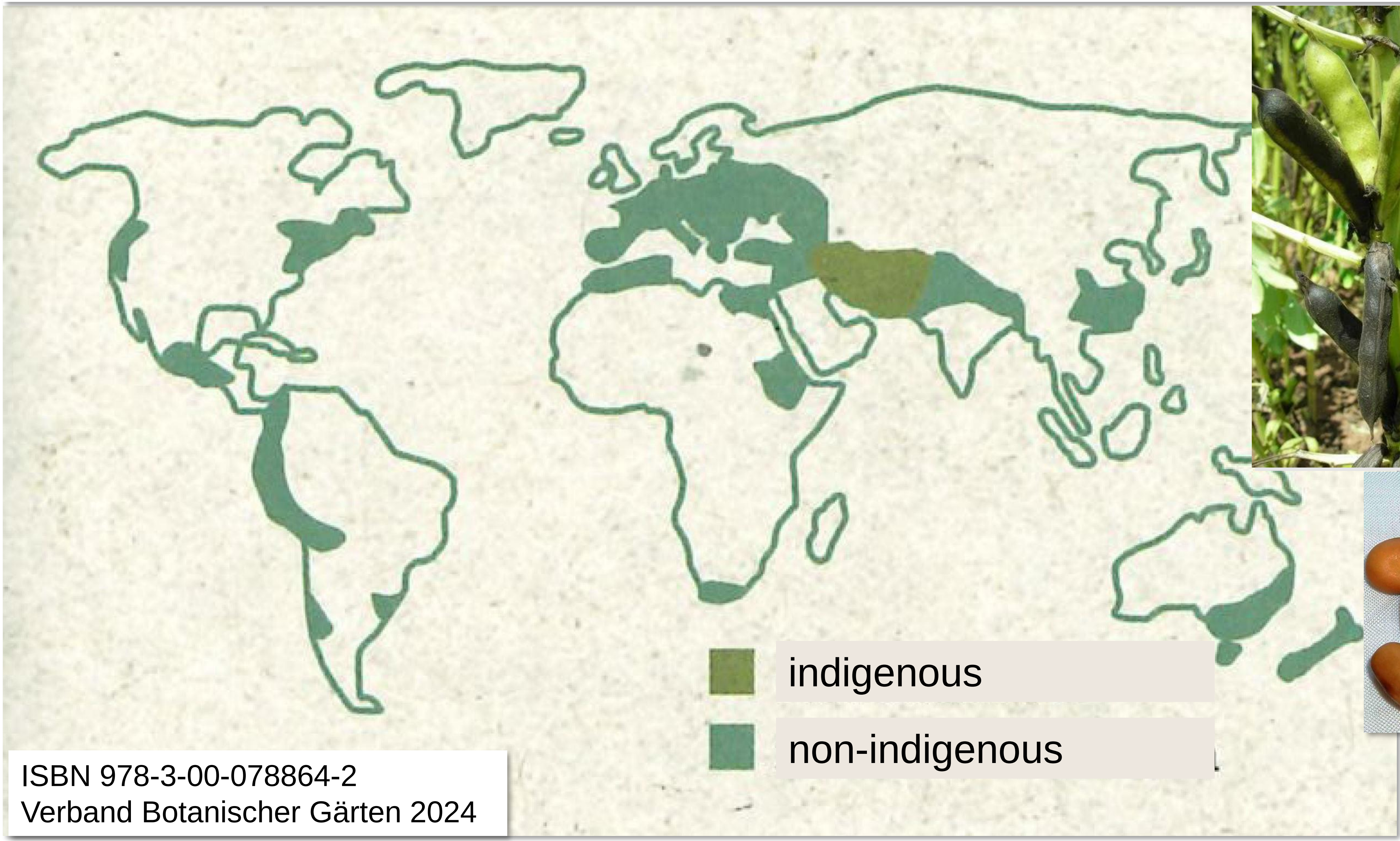
Die Bohne platzt vor Lachen

Serie 200 Jahre Märchen der Brüder Grimm / Teil 7: „Strohhalm, Kohle und Bohne auf der Reise“

Fairy tale: Straw, bean and coal on a journey



Faba bean around the globe. Not in the humid tropics.



ISBN 978-3-00-078864-2
Verband Botanischer Gärten 2024

Faba bean realizes heterosis, suppresses weed, assimilates much Ndfa;
There are spring beans and winter beans (Link, 2009. ISSN 0027-7479).

‚My' comparison between combine-harvested pulses in Germany

Species	Maturity fits	Soil demands	Weed suppr.	Symbiotic perform.	Autochth. Rhizobia	Protein Content	Protein Quality	Option for Food	Option for Autmn sowing	Option for Hete-rosis	Σ
Soy	NO	OK	NO	-	-	>40%	+	YES	NO	NO	4
Pea	YES	OK	NO	+	+	25%	-	+ / -	YES	NO	5
Sweet Lupine (*l/a/a*)	YES	pH	NO	+	+	>35%	+	YES	NO	NO	6
Faba bean	YES	OK	YES	++	+	30%	-	+ / -	YES	YES	7

Faba bean
Traditional object of research in Gatersleben

DIE KULTURPFLANZE

MITTEILUNGEN

AUS DEM ZENTRALINSTITUT
FÜR GENETIK UND KULTURPFLANZENFORSCHUNG
GATERSLEBEN
DER
AKADEMIE DER WISSENSCHAFTEN DER DDR

HERAUSGEGEBEN VON

H. BÖHME, S. DANERT, W. R. MÜLLER-STOLL, R. RIEGER,
A. RIETH, H. SAGROMSKY, H. STUBBE

SCHRIFTLEITUNG: S. DANERT

BAND XX

Die Stellung von *Vicia faba* L. in der Gattung *Vicia* L. und Betrachtungen zur Entstehung dieser Kulturart

Peter Hanelt

von Peter Hanelt, Helga Schäfer und Jürgen Schultze-Motel

(Eingegangen am 3. Februar 1972)

Die folgenden Ausführungen sind eine abschließende Auswertung der vorangegangenen Beiträge von Schultze-Motel (1972) und Hanelt (1972, 1972a) sowie von Abschnitten einer Dissertation von Schäfer (1972), soweit sie sich auf die systematische Stellung der Ackerbohne in ihrer Gattung und auf Abstammungsfragen dieser Art beziehen.

DIE STELLUNG VON *VICIA FABA* IN DER GATTUNG *VICIA*

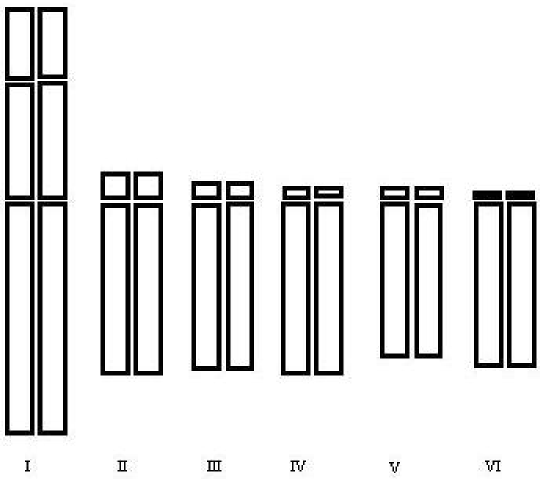
Faba bean, a traditional object of research in Gatersleben

Chromosome Research 1998, **6**, 219–230

Molecular–cytogenetic characterization of the *Vicia faba* genome – heterochromatin differentiati plication patterns and sequence localization

Jörg Fuchs, Sabine Strehl, Andrea Brandes, Dieter Schweizer & Ingo Schubert

Received 28 October 1997; received in revised form 3 January 1998; accepted for publication by J. S. Heslop-Harrison 8 January 1998



Faba bean, a traditional object of research in Gatersleben

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Molecular–cytogenetic characterization of the *Vicia faba* genome – heterochromatin differentiati plication patterns and sequence localization

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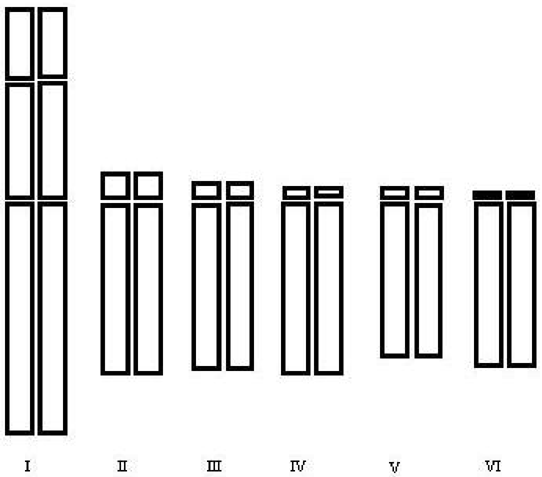
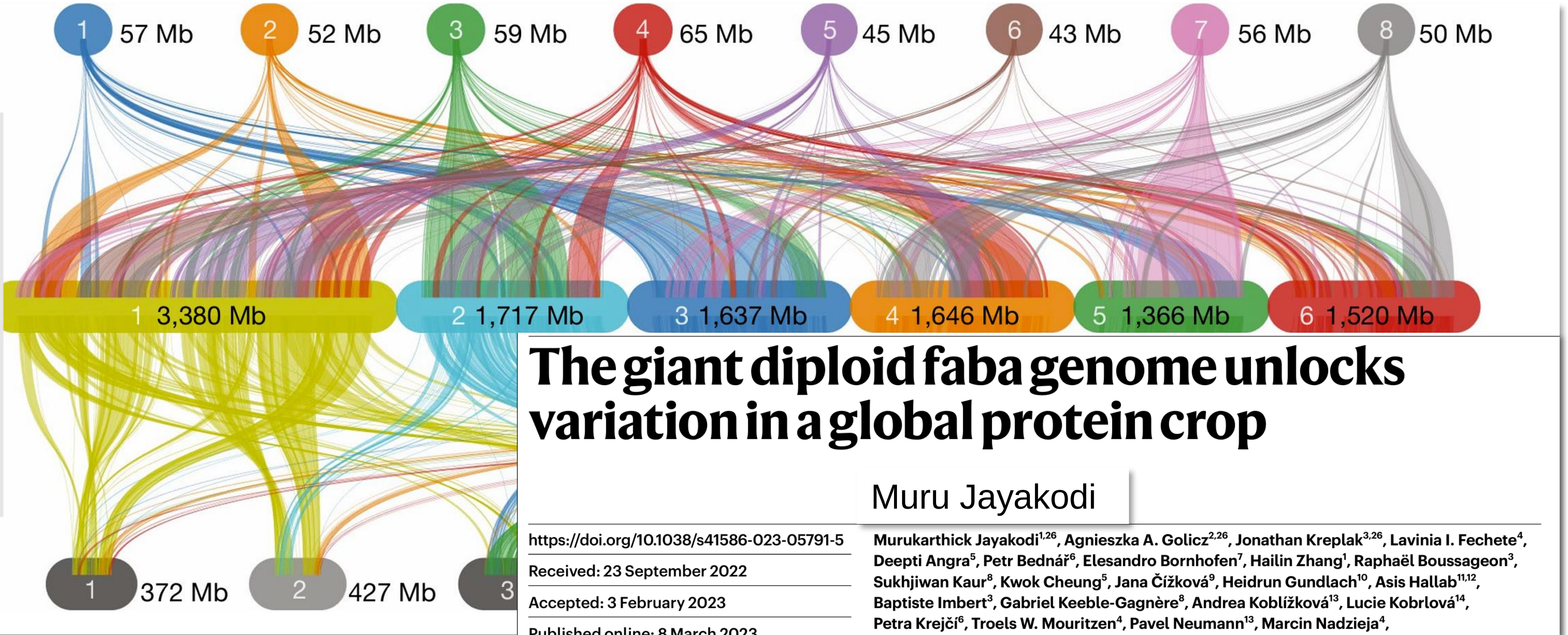


Faba bean, a traditional and current object of research in Gatersleben

Evolution and Synteny analysis in faba bean.
Syntenic relationship of faba bean (middle) with *Medicago* (top) and pea (bottom).



The giant diploid faba genome unlocks variation in a global protein crop

Muru Jayakodi

https://doi.org/10.1038/s41586-023-05791-5

Received: 23 September 2022

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Open access

Check for updates

Murukarthick Jayakodi[1,26], Agnieszka A. Golicz[2,26], Jonathan Kreplak[3,26], Lavinia I. Fechete[4], Deepti Angra[5], Petr Bednář[6], Elesandro Bornhofen[7], Hailin Zhang[1], Raphaël Boussageon[3], Sukhjiwan Kaur[8], Kwok Cheung[5], Jana Čížková[9], Heidrun Gundlach[10], Asis Hallab[11,12], Baptiste Imbert[3], Gabriel Keeble-Gagnère[8], Andrea Koblížková[13], Lucie Kobrlová[14], Petra Krejčí[6], Troels W. Mouritzen[4], Pavel Neumann[13], Marcin Nadzieja[4], Linda Kærgaard Nielsen[15], Petr Novák[13], Jihad Orabi[16], Sudharsan Padmarasu[1], Tom Robertson-Shersby-Harvie[5], Laura Ávila Robledillo[13], Andrea Schiemann[16], Jaakko Tanskanen[17], Petri Törönen[18], Ahmed O. Warsame[5], Alexander H. J. Wittenberg[19], Axel Himmelbach[1], Grégoire Aubert[3], Pierre-Emmanuel Courty[3], Jaroslav Doležel[9], Liisa U. Holm[18], Luc L. Janss[7], Hamid Khazaei[17], Jiří Macas[13], Martin Mascher[1,20], Petr Smýkal[14], Rod J. Snowdon[2], Nils Stein[1,21], Frederick L. Stoddard[22,23], Jens Stougaard[4], Nadim Tayeh[3], Ana M. Torres[24], Björn Usadel[11,25], Ingo Schubert[1], Donal Martin O'Sullivan[5]✉, Alan H. Schulman[17,18,23]✉ & Stig Uggerhøj Andersen[4]✉

V. faba is somewhat recalcitrant, stubborn, obstinate; behaves a bit like a Diva

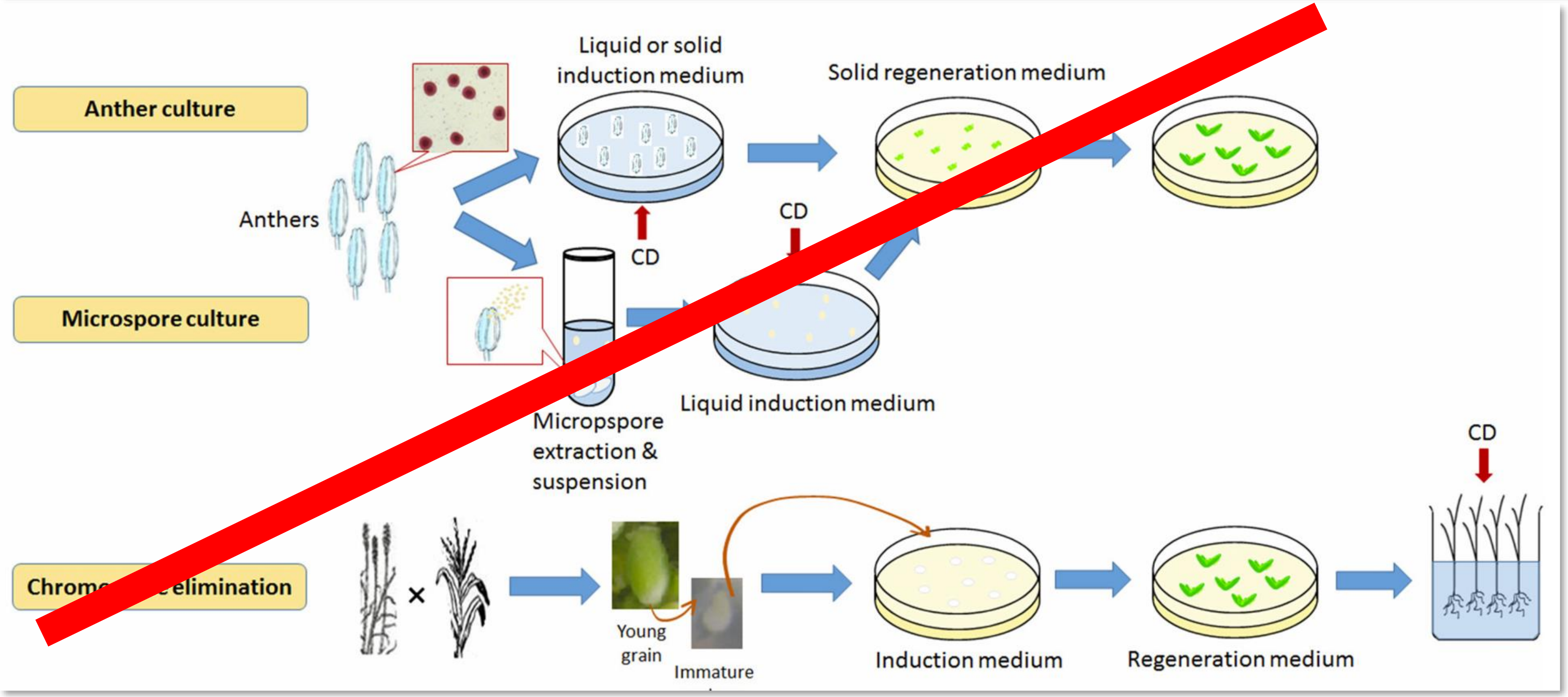
V. faba is somewhat recalcitrant, stubborn, obstinate; behaves a bit like a Diva

Reluctant to tissue culture methods, including micro-propagation, agrobacterium-mediated transformation, protoplast regeneration, CMS.

No procedure for obtaining haploid/DH regenerants has been developed.

https://doi.org/ 10.3390/agriculture14071031 Skrypkowski & Kiełkowska, 2024.

https://doi.org/10.1016/j.jplph.2009.01.011



DOI 10.3389/fpls.2017.01786

More than 2 generations per year?
Why should I behave in a particularly cooperative manner?

Received: 20 July 2020 | Revised: 27 August 2020 | Accepted: 7 September 2020
DOI: 10.1111/pbr.12868

Plant Breeding WILEY

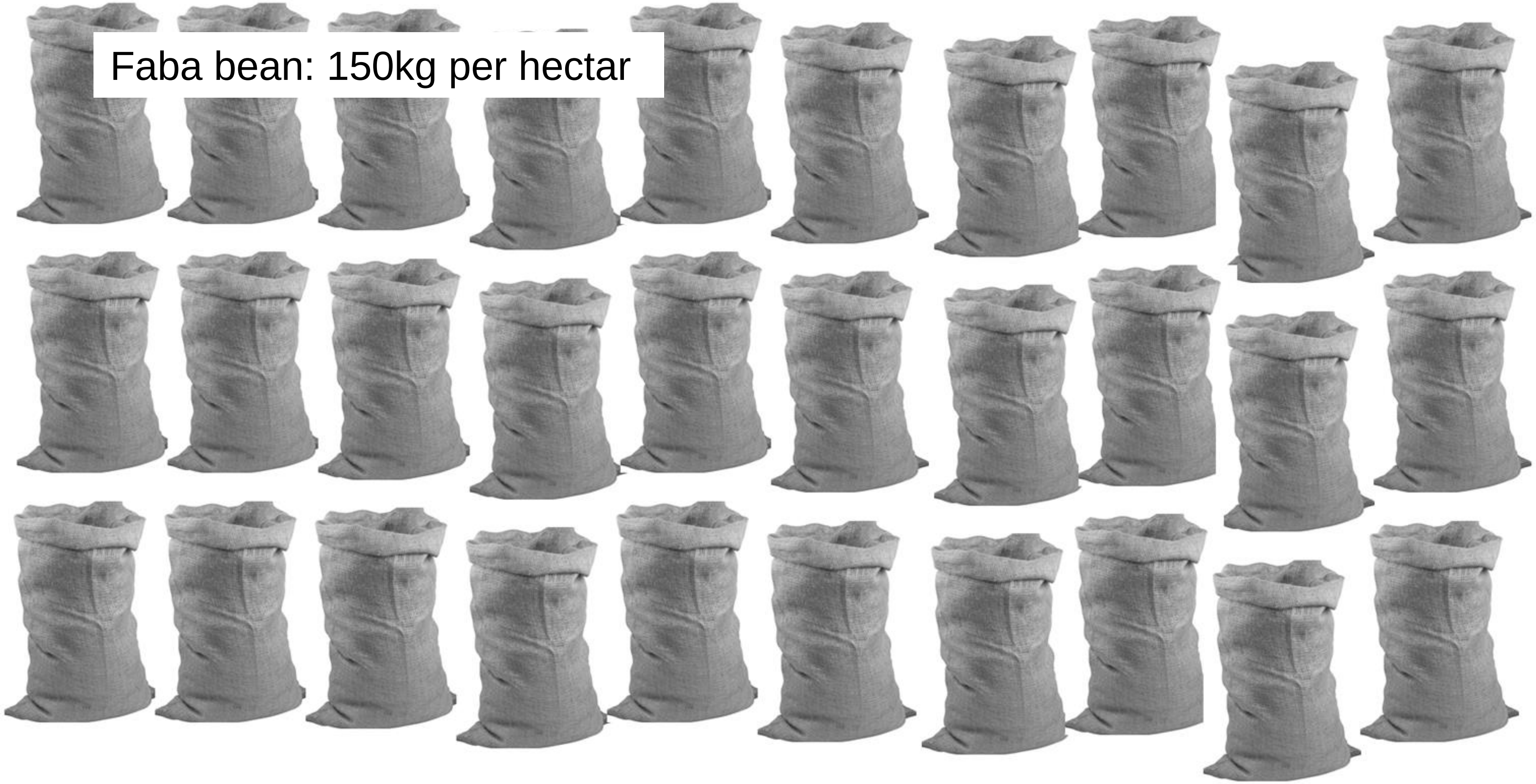
ORIGINAL ARTICLE

Shortening the generation cycle in faba bean (*Vicia faba*) by application of cytokinin and cold stress to assist speed breeding

Saeid Mobini | Hamid Khazaei | Thomas D. Warkentin | Albert Vandenberg

Many generations to go from few-plants to farmers’ field scale.
Using a non-perfect CMS-system ? ... maybe in *B. napus*, not in *V. faba*.

Canola: ~3kg seed per hectar



Two PhD thesis at Göttingen; cooperation with Christian Möllers and team.

Wijaya, 2003. Interspecific cross (proto-plast fusion & regeneration; or embryo-rescue). Zero success.

V. michauxii

Kramer, 2002. Genetic transformation *via Agro-bacterium t.* Very demanding.

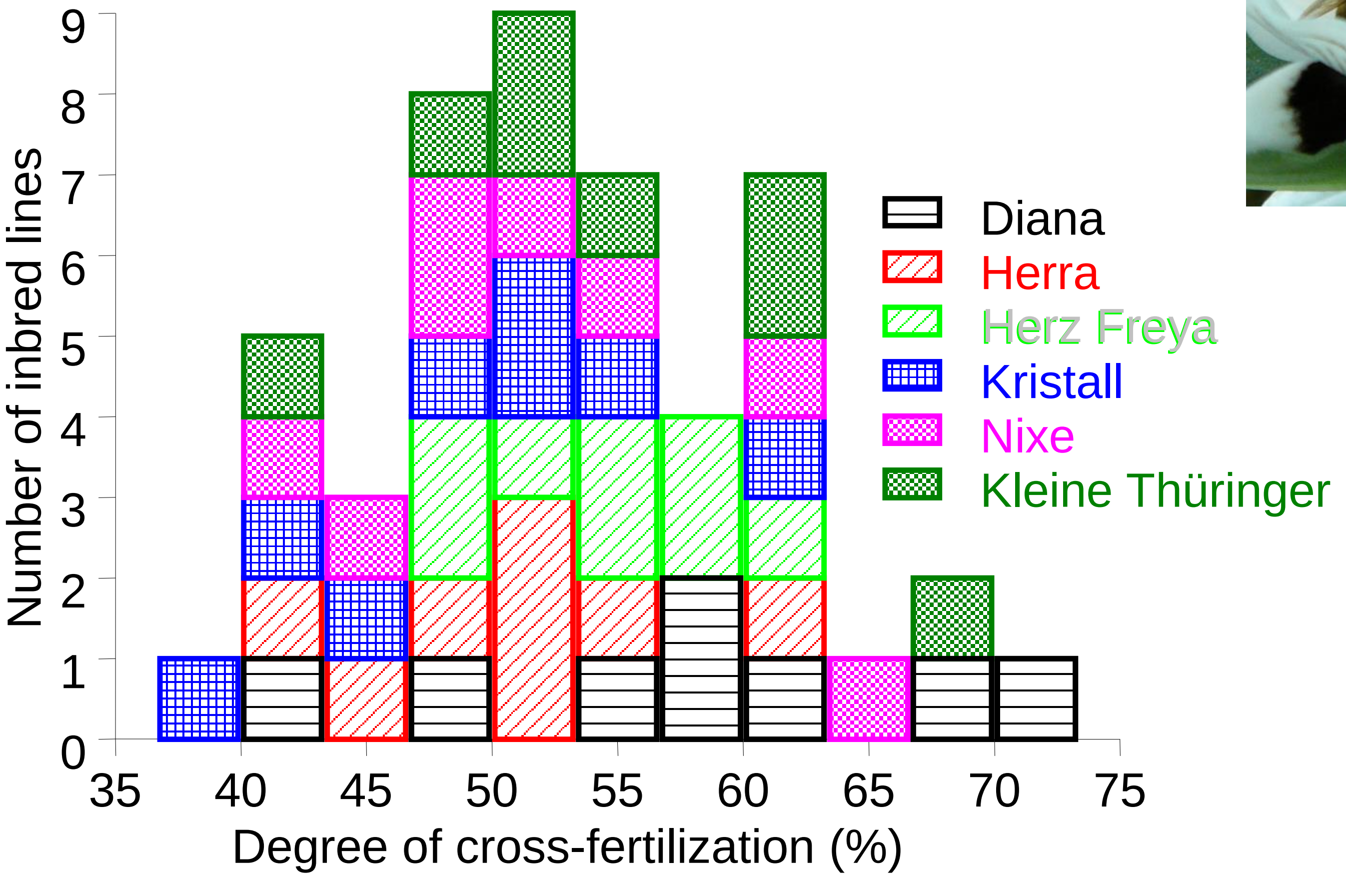
Rod Snowdon’s group in Giessen, *via* their recent, international project ‘Accelerating Crop Genetic Gain’, conduct research on *Vicia faba* including in vitro regeneration from meristem, *A. bacterium* mediated transformation ... and the like.

Skip Breeding Objectives …
Enter into Breeding Methodology

Faba bean is partially cross- and partially self-fertilizing, with a very marked genetic (and environmental) variation for this feature.

Degree of cross-fertilization of 48 faba bean inbred lines

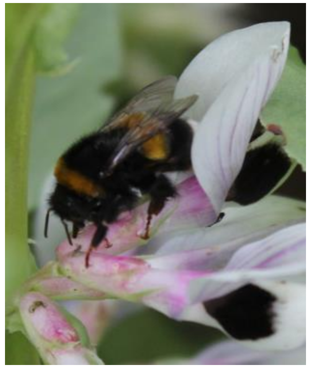
Mean = 53.7%; h^2 = 0.75 (1site, 3 yrs); Link et al., 1994



Apis millifera

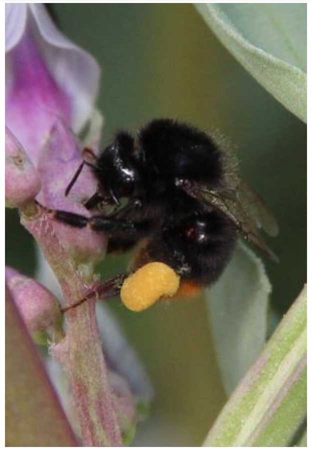
Bombus hortorum

Bombus terrestris



Bombus pascuorum

Bombus lapidarius

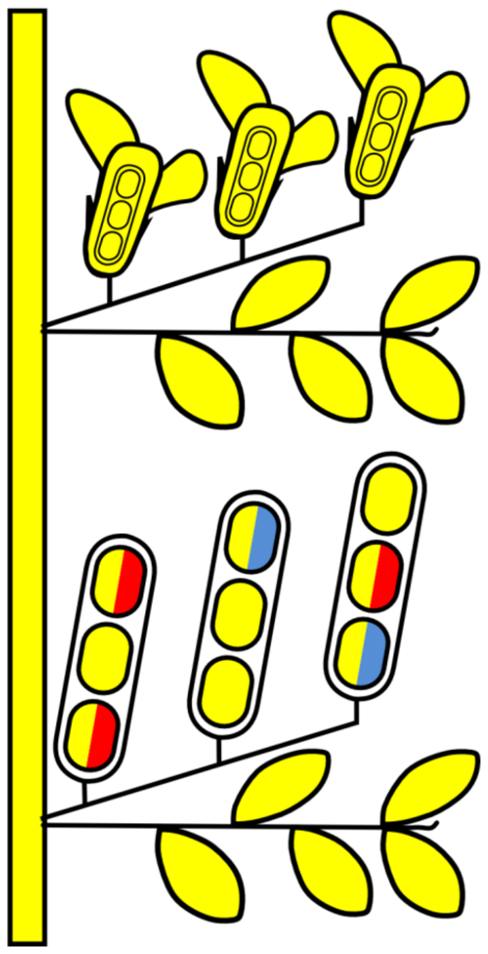


© Brünjes

Partial allogamy *aka* mixed mating (partial selfing and partial random mating):
Mating system (reproductive mode) of hermaphrodite plants which are neither strictly self-fertilizers nor strictly cross-fertilizers.

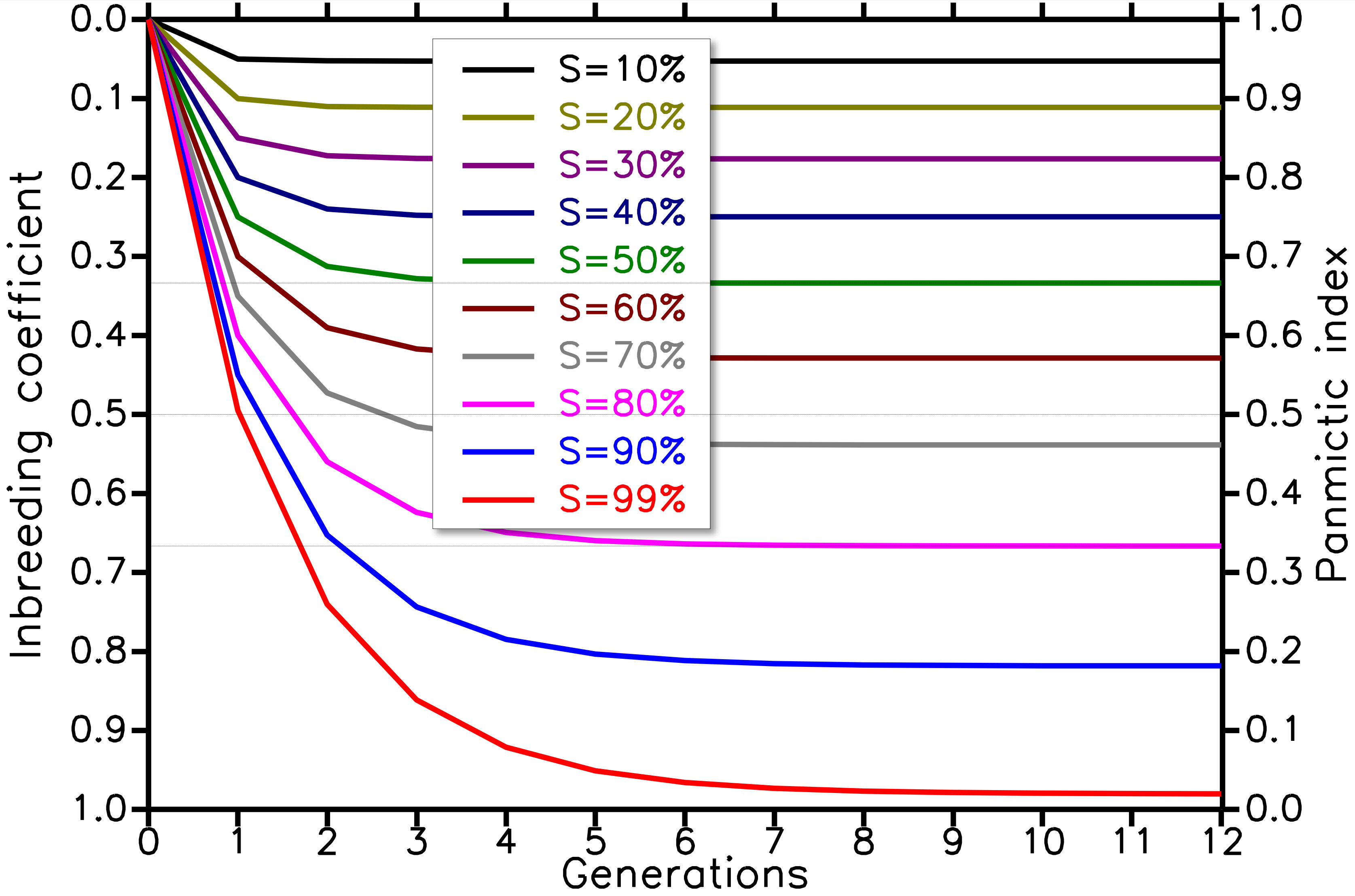
With partial allogamy, across generations the population strives towards an equilibrium value F_∞, i.e. towards a population average of inbreeding F_∞.

$$F_\infty = S / (2 - S)$$



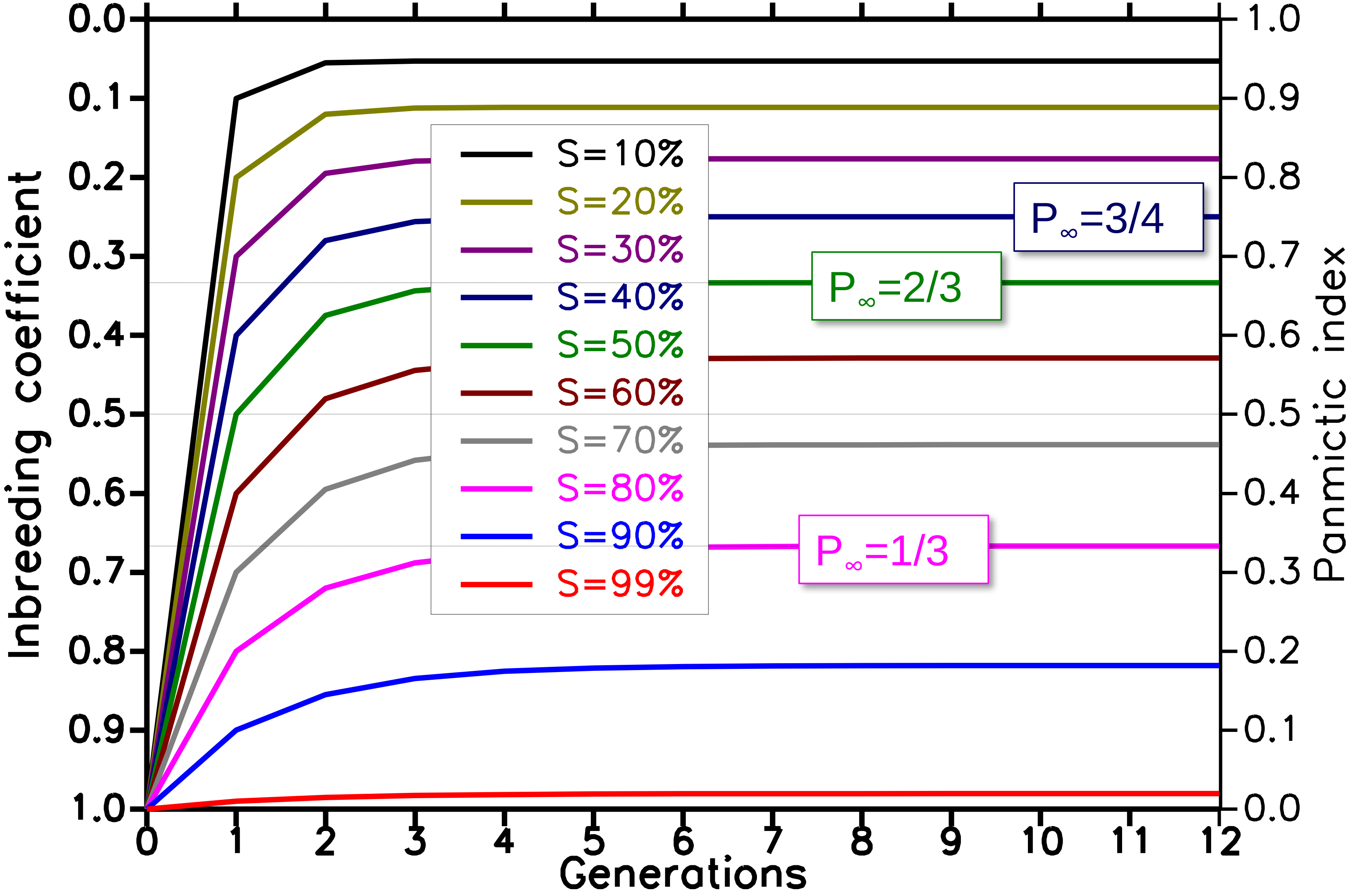
© Brünjes 2017

Mix many zero-inbred genotypes and let them go through many generations of their natural mixed-mating behaviour.
Finally they reach their population mean equilibrium inbreeding level F∞.

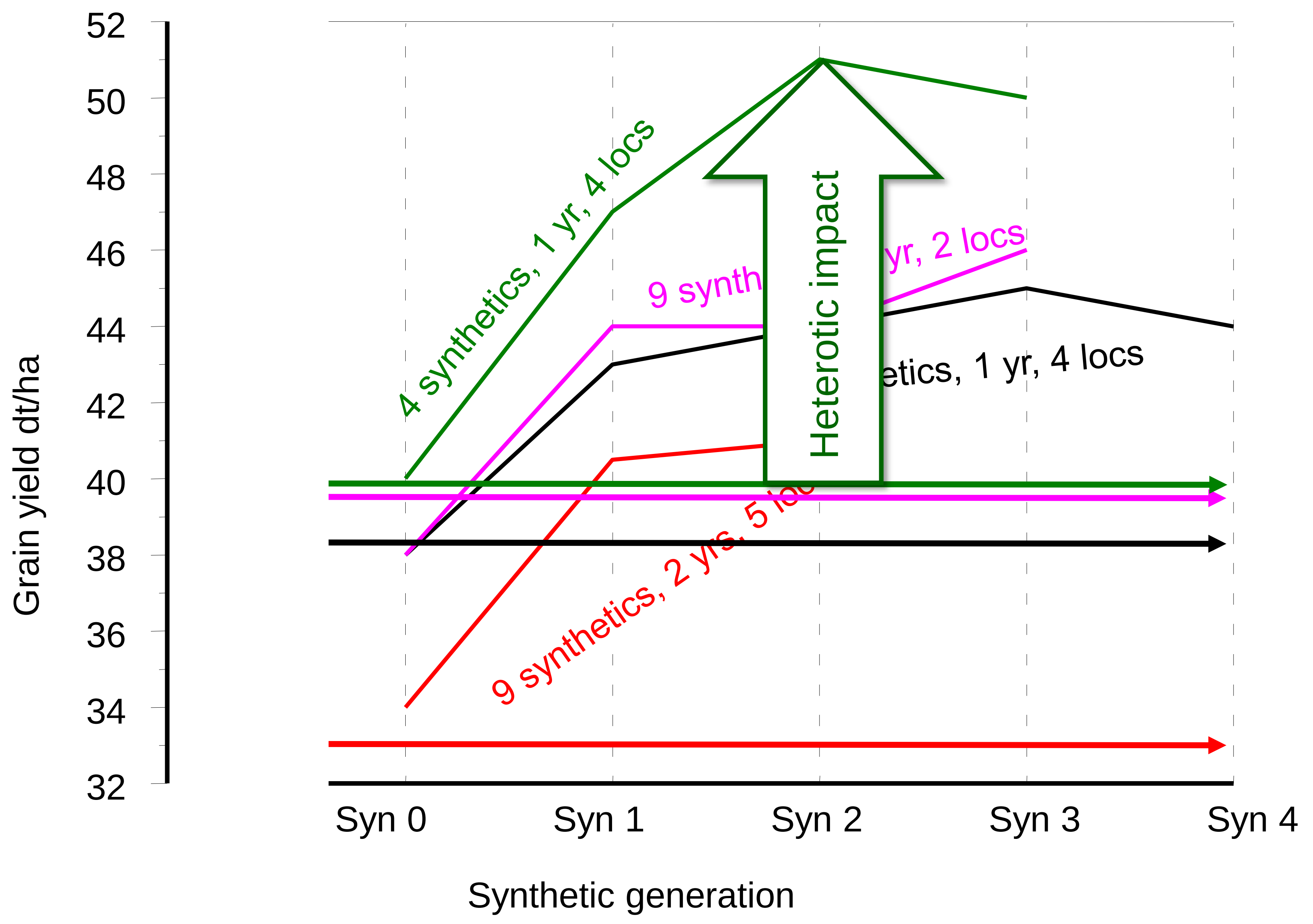


Mix many fully-inbred genotypes and let them go through many generations of their natural mixed-mating behaviour.

Finally they reach their population mean equilibrium inbreeding level F∞.



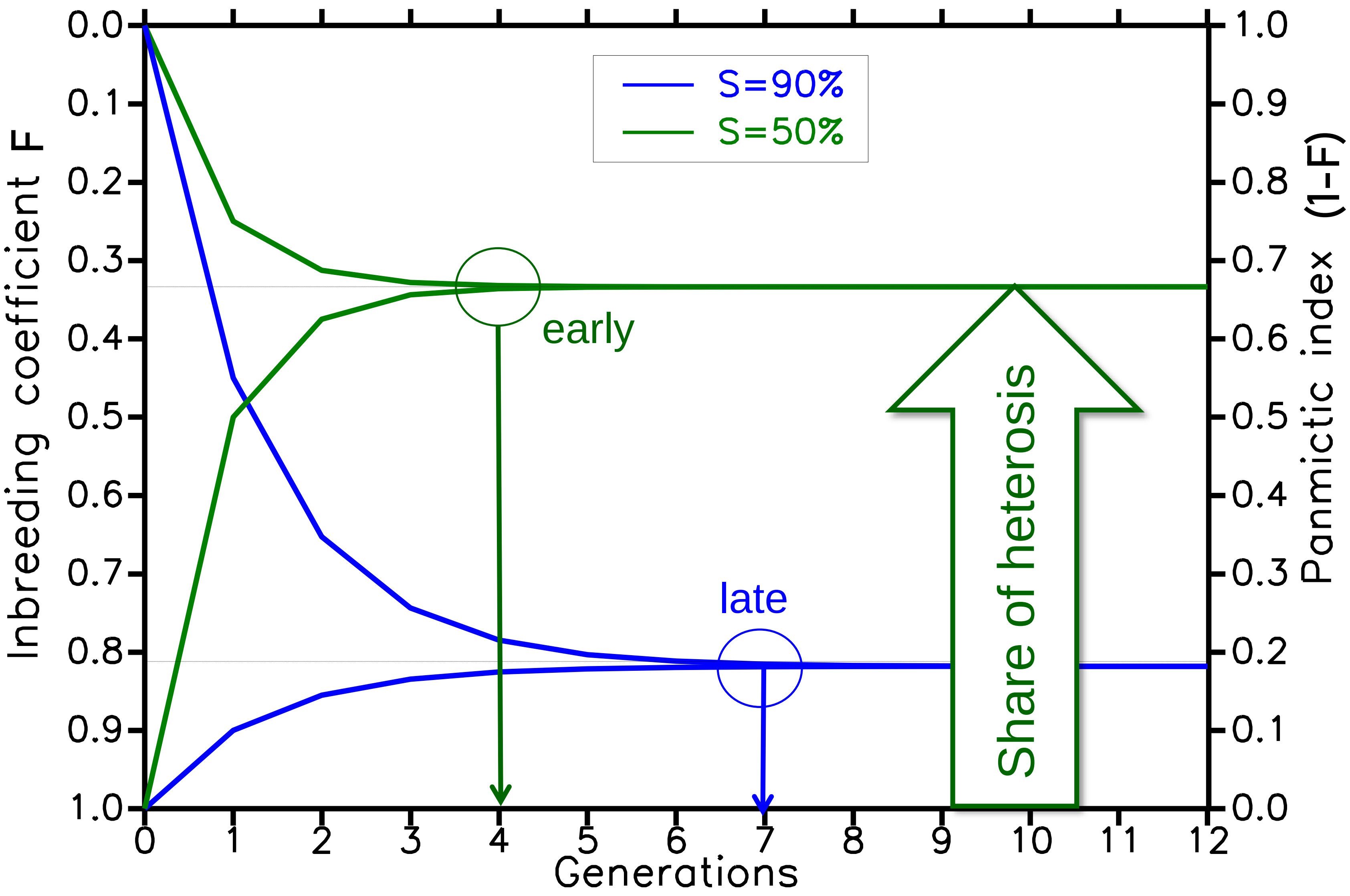
Superiority of Syn generations > homozygous components (Stelling *et al*., 1994)



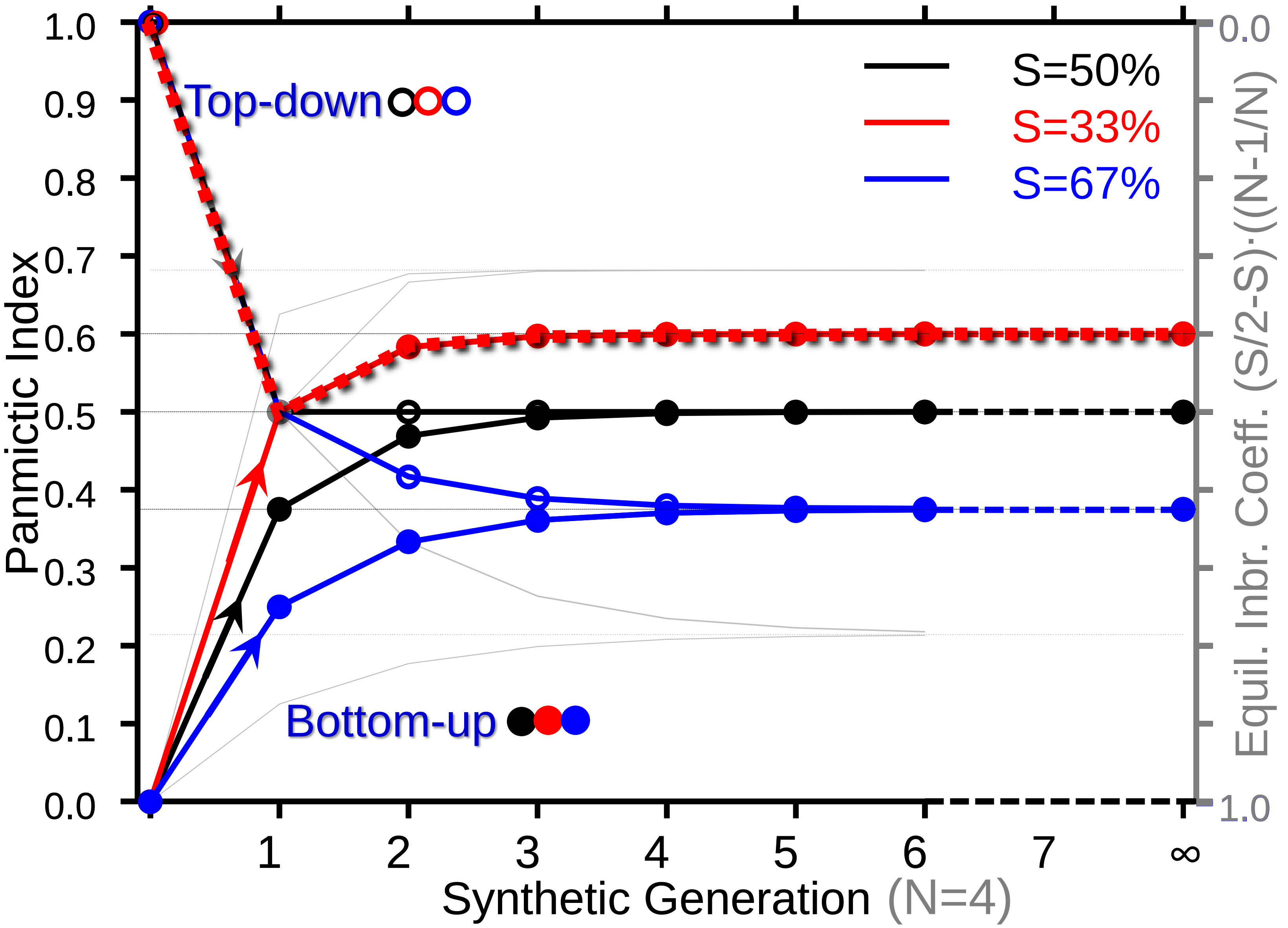
Synthetic *cvs* reliably outyield the mixture of their homozygous components.

Whether a synthetic reliably outyields the best of its components is a different question.

The lower the degree of self-fertilization (the higher the degree of cross-fertilization), the faster (earlier) the approach to equilibrium level F∞.

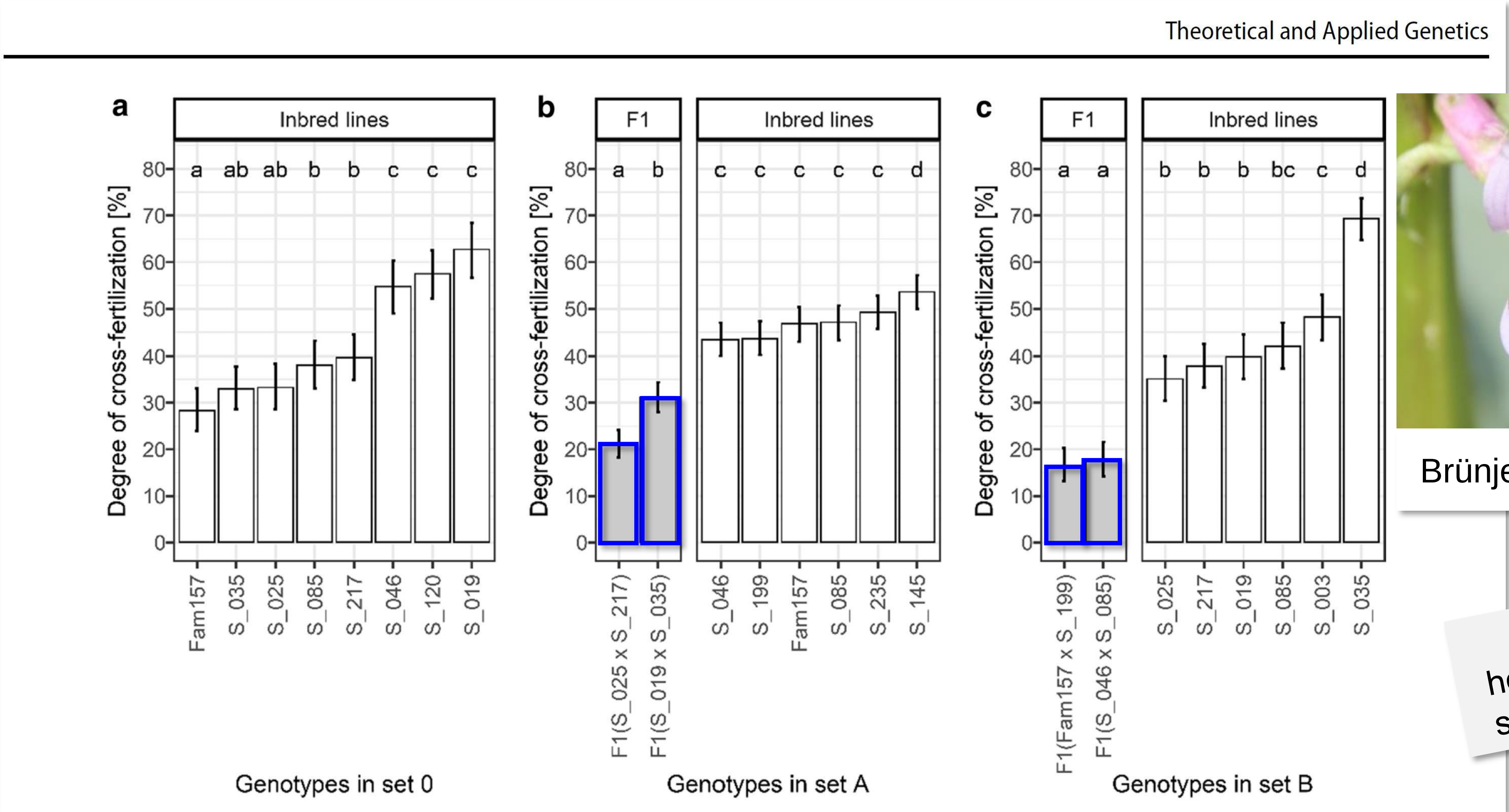


So-called synthetics are initiated by mixing several pure lines (bottom-up). Alternatively we could instead create their F1's and mix their F2's (top-down); cons and pros.



Reese,
Link,
Brünjes, 2024

Degrees of self-fertilization of *Vicia faba*;
hybrids outcross markedly less than inbred genotypes (Brünjes and Link, 2021).



Brünjes and Link, 2021

Positive heterosis for % self-fertilization

Change of Panmictic Index across several generations of multiplication starting with very many genetically unrelated inbreds.

Cross-fertilization either C=70% or C=30%.

Heterosis for C either zero or strong
(i.e. 90% reduction of C in F1).

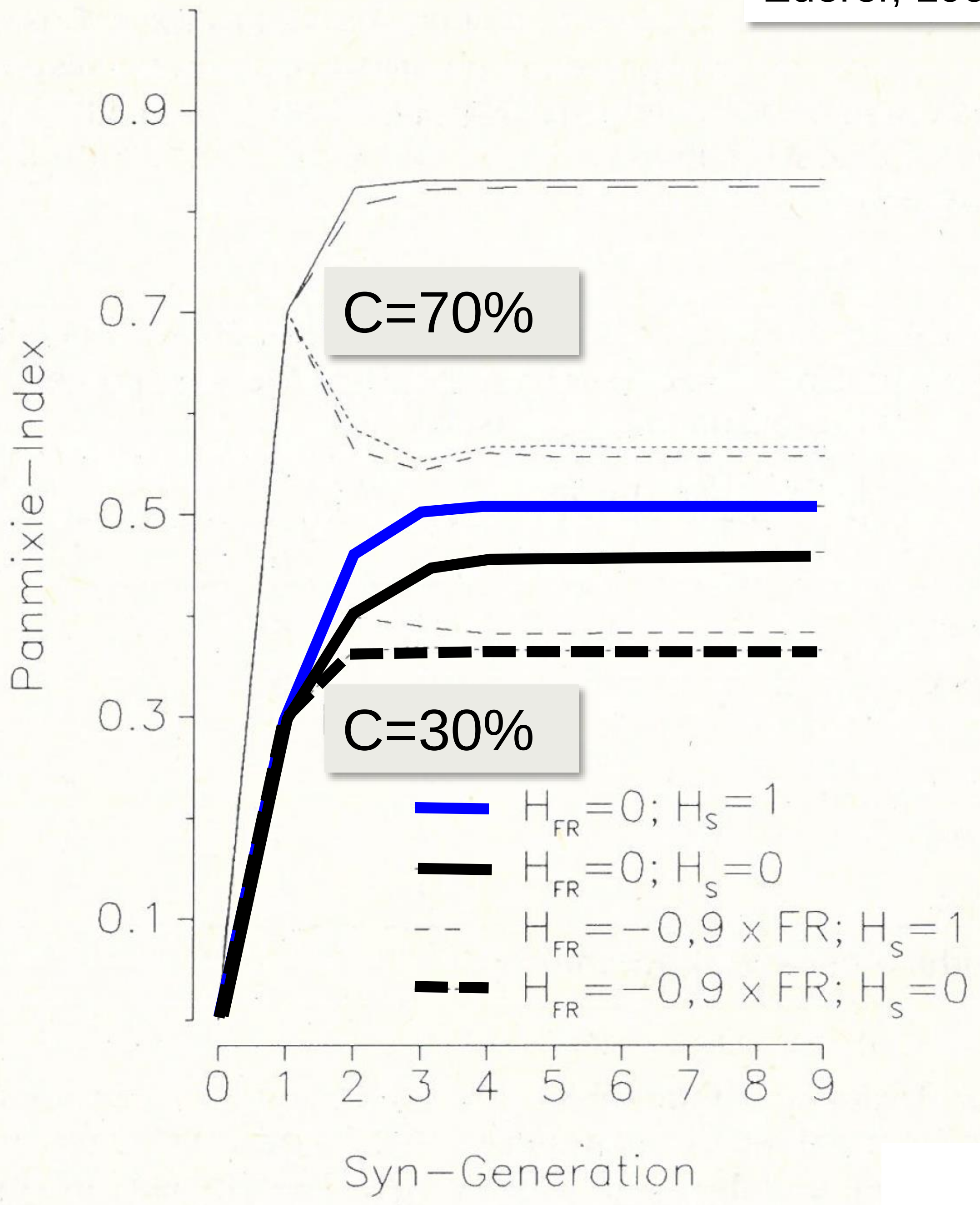
Heterosis for number of seeds per plant either zero or double-number in F1.

Ederer, 1991: Zuchtmethodische Modellrechnungen zur Leistungsentwicklung und Leistungsvorhersage synthetische Sorten bei partieller Allogamie am Beispiel der Fababohne (*Vicia faba* L.).
Diploma thesis, University of Hohenheim.

Positive heterosis for % self-fertilization

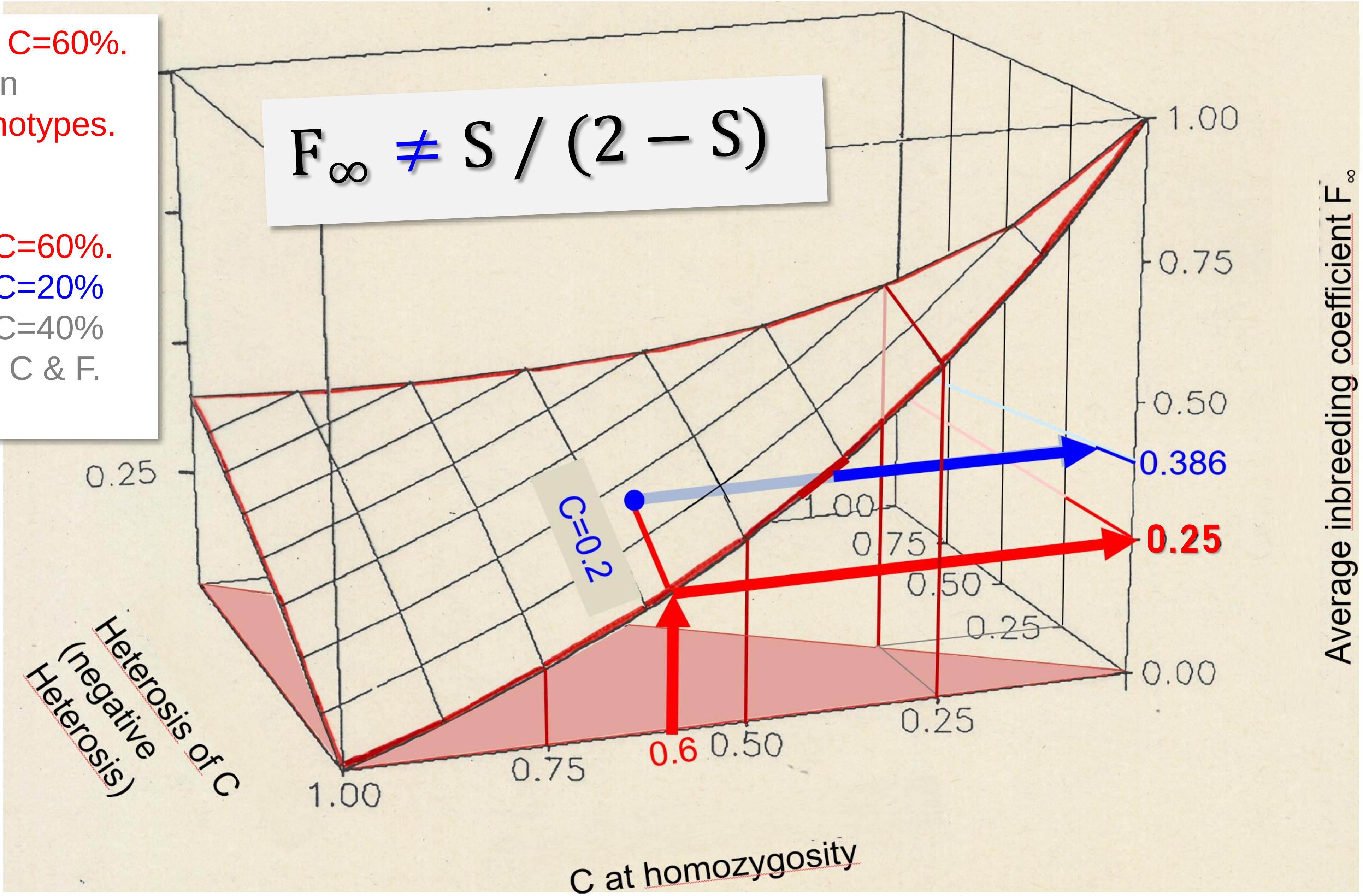
Negative heterosis for % cross-fertilization

Ederer, 1991



Degree of cross-fertilization C=60%.
i.e. degree of self-fertilization
S=40%. Constant for all genotypes.
$F_\infty = S/(2-S) = 0.25$

Homozygous genotypes: C=60%.
Non-inbred genotypes: C=20%
Half-inbred genotypes: C=40%
Linear relationship between C & F.
$F_\infty = 0.386$



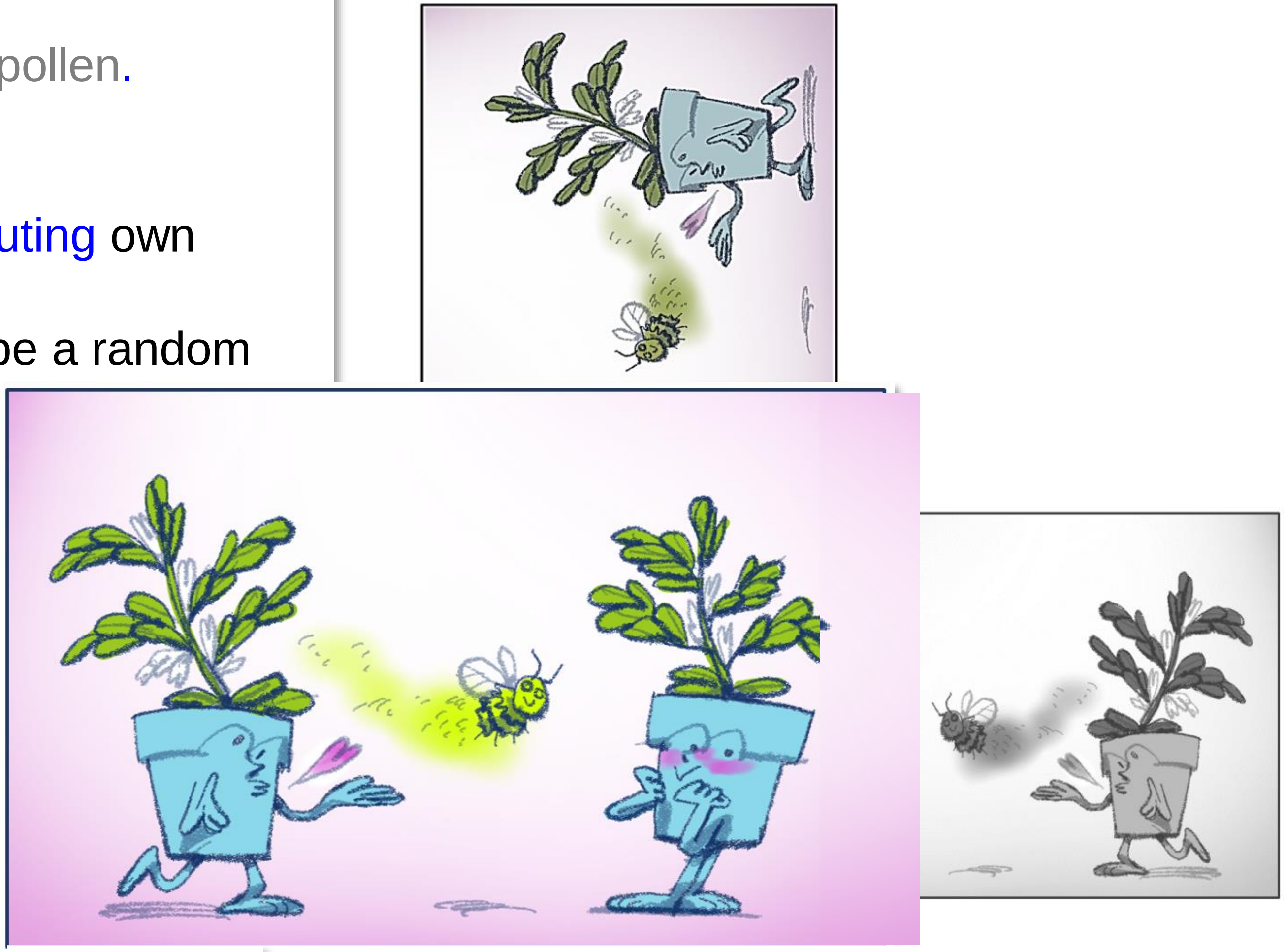
Link 1994; Brünjes 2020

More deviations from simple-minded model.

Degree of cross-fertilization:
A character of the genotype which accepts cross-pollen.

Yet.
Will all pollen-donors be equally efficient in distributing own pollen to other plants?
Is the cross-fertilized part of offspring of a genotype a random sample of the pollen that is offered from the surrounding pollinators … ?

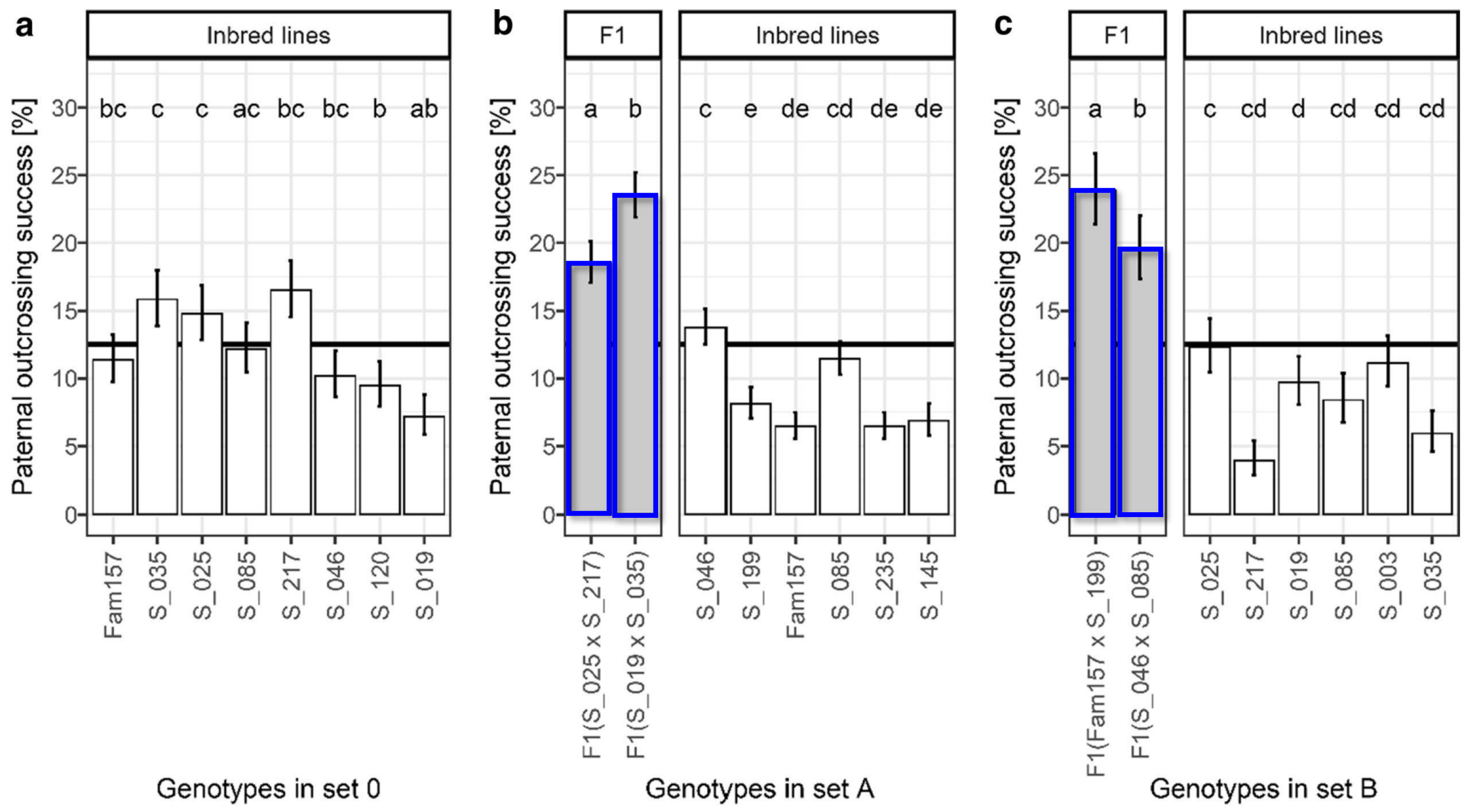
Do genotypes differ in their
Paternal Outcrossing Success P?



More deviations from simple-minded model.

Are all available pollon donors represented in equal share when a plant accepts cross-pollen for cross-fertilization?
Mean: Is the outcrossing truly ‚random'?

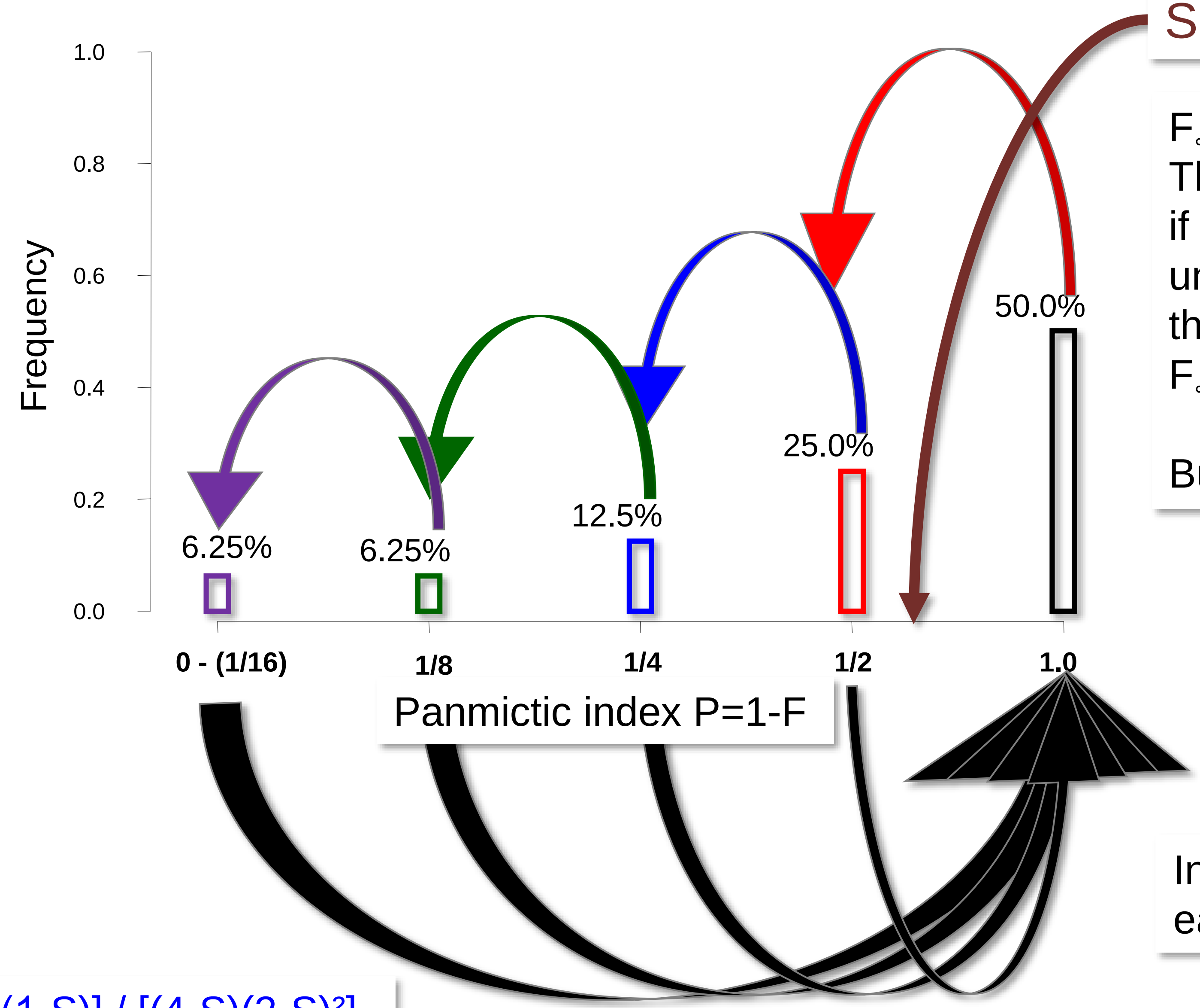
Paternal outcrossing success P. **Bold horizontal line** indicates P= 1/8 = 12.5%
... as should be if truly 'random'.
Brünjes and Link, TAG, 2021.



Brünjes and Link, 2021

Even more deviations from simplicity. Partially allogamy creates (even if gametes show LD=0) identity disequilibrium ($\eta \neq 0$) among the genotypes.

$S=½; F_\infty = [S/(2-S)] = ⅓; P_\infty = ⅔$



F_∞ says:
The average inbreeding coefficient – if the population propagates with S, undisturbed for many generations - this average is at
$F_\infty = S/(2-S)$

But: Nobody is at $F_\infty = S/(2-S)$

In equilibrium, population is well-recombined, each outcrossing creates non-inbred offspring

$\eta = [4S(1-S)] / [(4-S)(2-S)^2]$

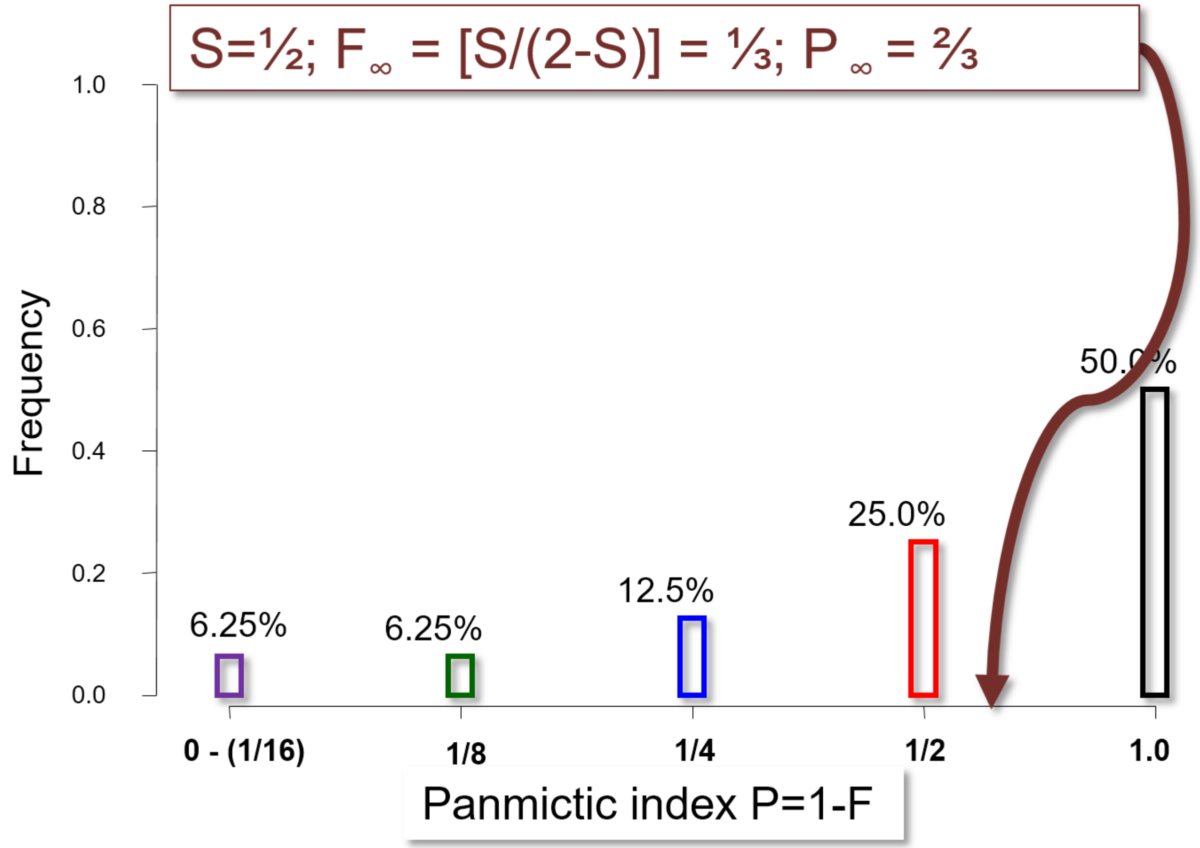
Tom Hanks in “Cast Away”. „Is anybody here?“ “Nobody is here”. $F_\infty = S / (2 - S)$

0 < S < 1: No mating creates offspring with $F_\infty = S/(2-S)$.

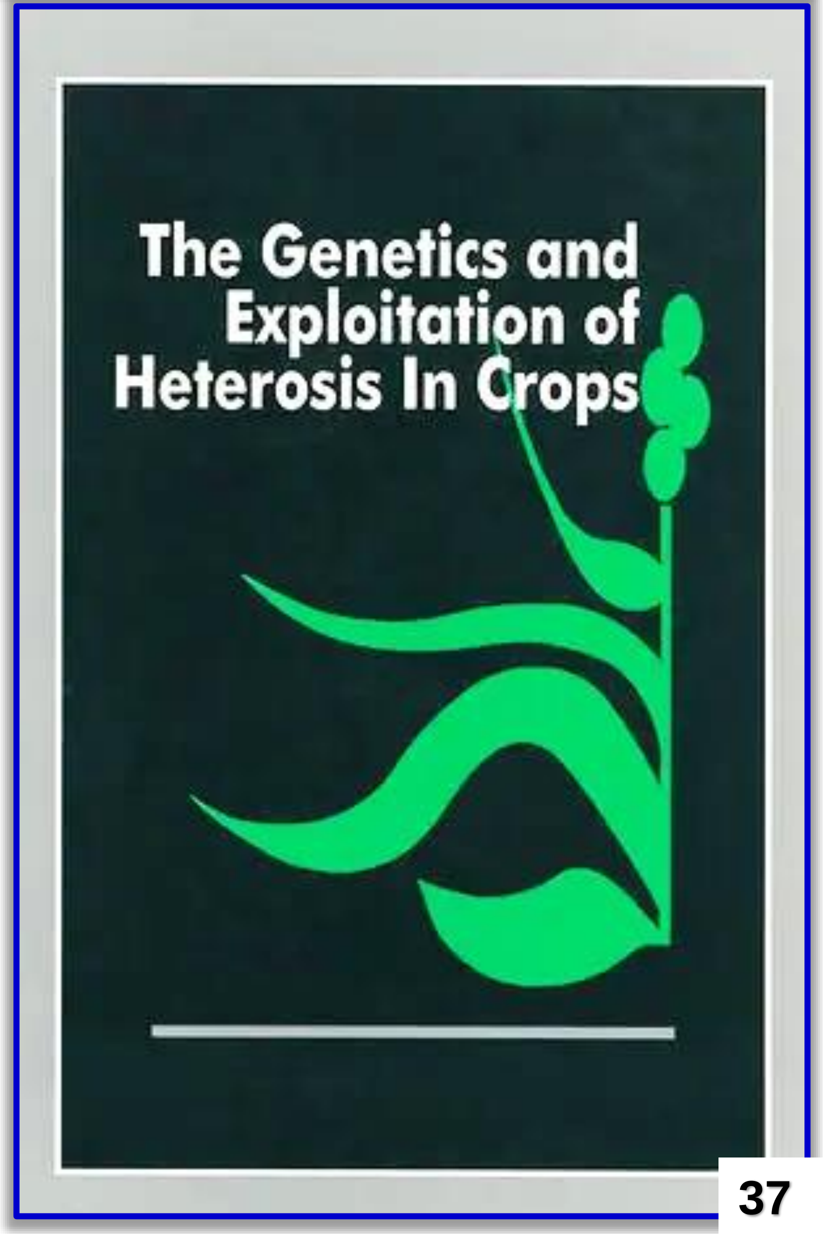
A mating creates either ... $F = ½ (1 + F_P)$ … which is F=1 if $F_P=1$ (from selfing)

or … F=0 (from outcrossing) …

$F_\infty = S/(2-S)$ is the average inbreeding coefficient, none of them has it. “Nobody is here”.

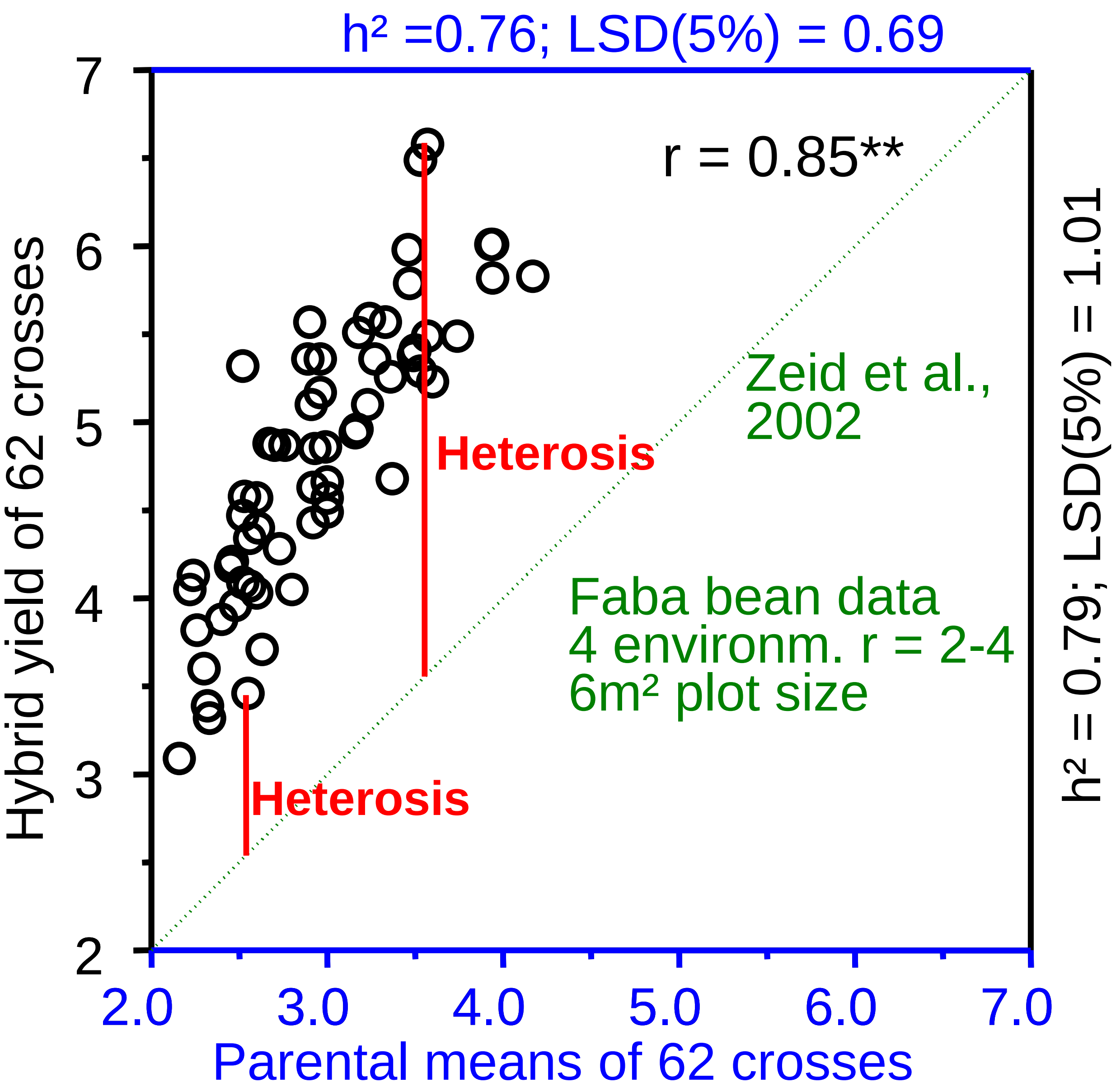


Heterosis. The excitement about all this outcrossing and inbreeding is because of ...
HETEROSIS – because of the opportunity to get higher yield with all else same.



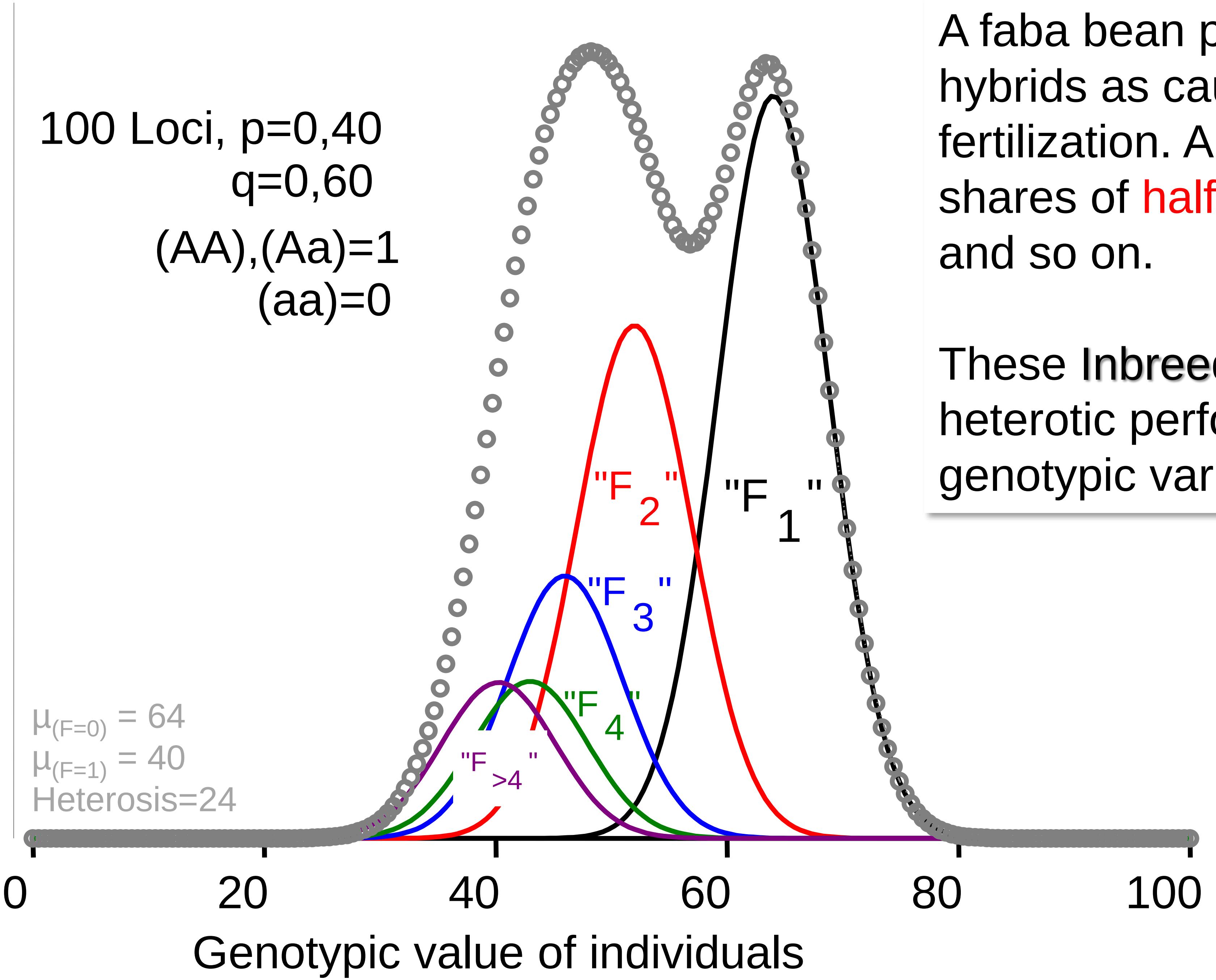
0-89118-549-6
1999. American Society of Agronomy Inc.
Crop Science Society of America, Inc.
Madison, Wisconsin, USA
JG Coors, S Panday

Marked heterosis for grain yield in faba bean, from ~ 20% to ~ 70%.



Zeid, M., C.-C. Schön and W. Link, 2004: Hybrid performance and AFLP-based genetic similarity in faba bean. Euphytica 139, 207 - 216.

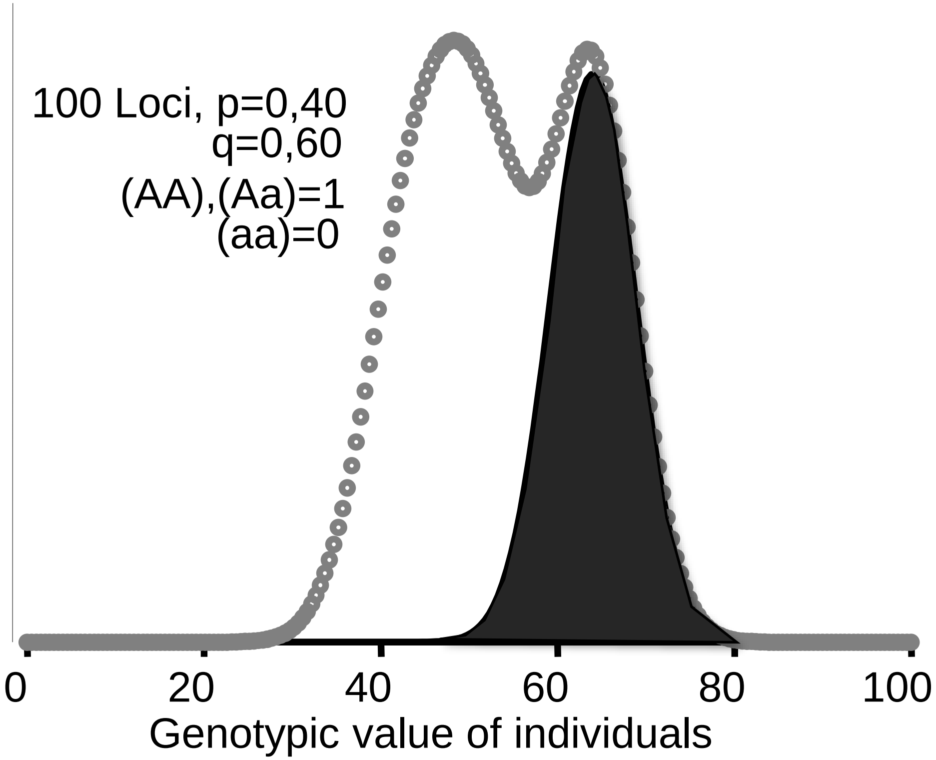
Link, W. and H. Stützel, 1995: Faba bean. Genetics. In: Diepenbrock, W. and H.C. Becker, (ed). Physiological Potentials for Yield Improvement of Annual Oil and Protein Crops. Advances in Plant Breeding, Vol. 17, Blackwell, Berlin, p. 239 - 278.



A faba bean population has C% F1-hybrids as caused by C% of cross-fertilization. And then correspondingly shares of half-inbreds and ¾-inbreds and so on.

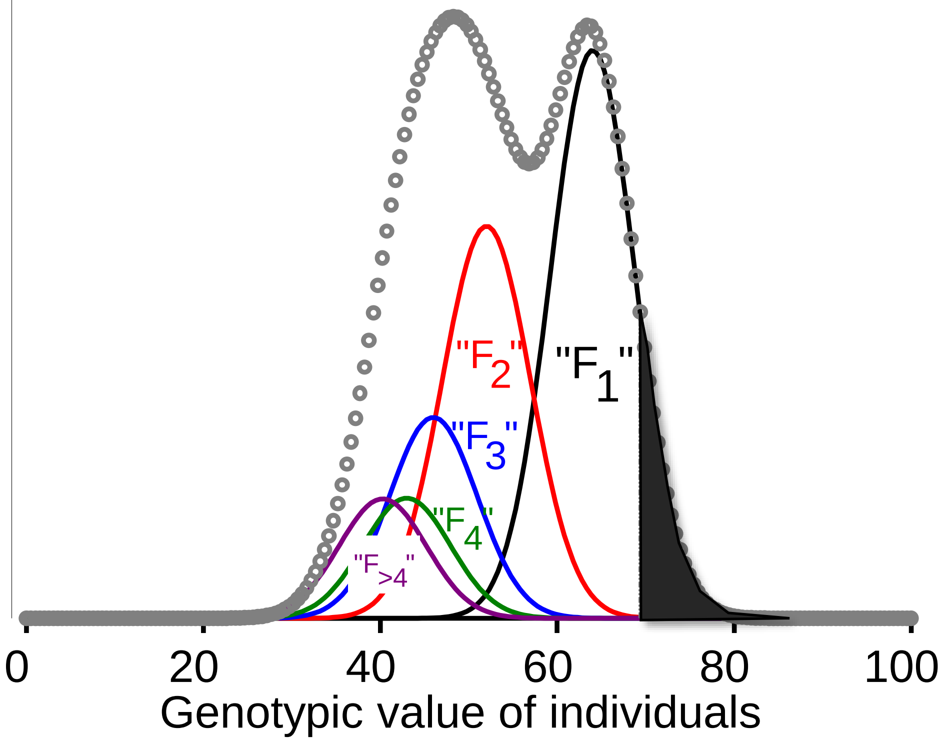
These Inbreeding Cohorts differ in heterotic performance and thus inflate the genotypic variance in such population.

Immediate *vs.* permanent gain from phenotypic mass selection



The worst idea for mass selection would be to select all those plants that come from outcrossing. Their offspring would, immediately, show superiority above the population and by and by strive to exactly the same level and composition as before, i.e., zero permanent gain from selection.

We must select much harder than what the % cross-fertilization tells!



53.8 -> 61.2 -> 58.9

Quantitative Genetics for diploid, partially allogamous populations

c=0.5
AA=Aa=1;aa=0
$\mu_{(F=0)} = 64$
$\mu_{(F=1)} = 40$
Heterosis=24
$\text{Heterosis}^2=576$

Modelling genotypic variance in partially allogamous populations
(Weir and Cockerham, 1977; Wright, 1987; Kelly and Williamson, 2000).
Example: S=50%; p(A)=0.40; a=d=½ across N=100 loci, LD=0.

Assumption: 2 alleles per locus … "Σ" is across loci

Additive variance $\sigma^2_A = \Sigma\, 2pq\, [\, a - (p - q)\, d]^2$ **17.28**
Dominance variance $\sigma^2_D = \Sigma\, [2\, p\, q\, d]^2$ **5.76**
Covariance of the α with the δ_{11} and δ_{22} -effects
$D_1 = \Sigma\, 2pq\, [a - (p-q)\, d]\, [(p-q)d]$ **-2.88**
Variance of the inbreeding depression
(i.e., variance of the δ_{11} and the δ_{22} effects)
$D^*_2 = \Sigma\, 4pq\, [(p - q)\, d]^2$ **0.96**
Square of the **total inbreeding depression**
$H^2 = [\Sigma\, 2\, p\, q\, d]^2$ **576**

$$\sigma^2_G = 4/3\, \sigma^2_A + 8/9\, \sigma^2_D + 4/3\, D_1 + 1/3\, D^*_2 + \eta\, (H^2 - \sigma^2_D) = \mathbf{97.05}$$

$\eta = [4S(1-S)] / [(4-S)(2-S)^2]$; S=50%, $\eta = 8/63 = 0.127$ [e:ta]

Breeding partially cross-fertilizing crops: The adequate breeding category and method is not self-evident

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Division of Plant Breeding Methodology

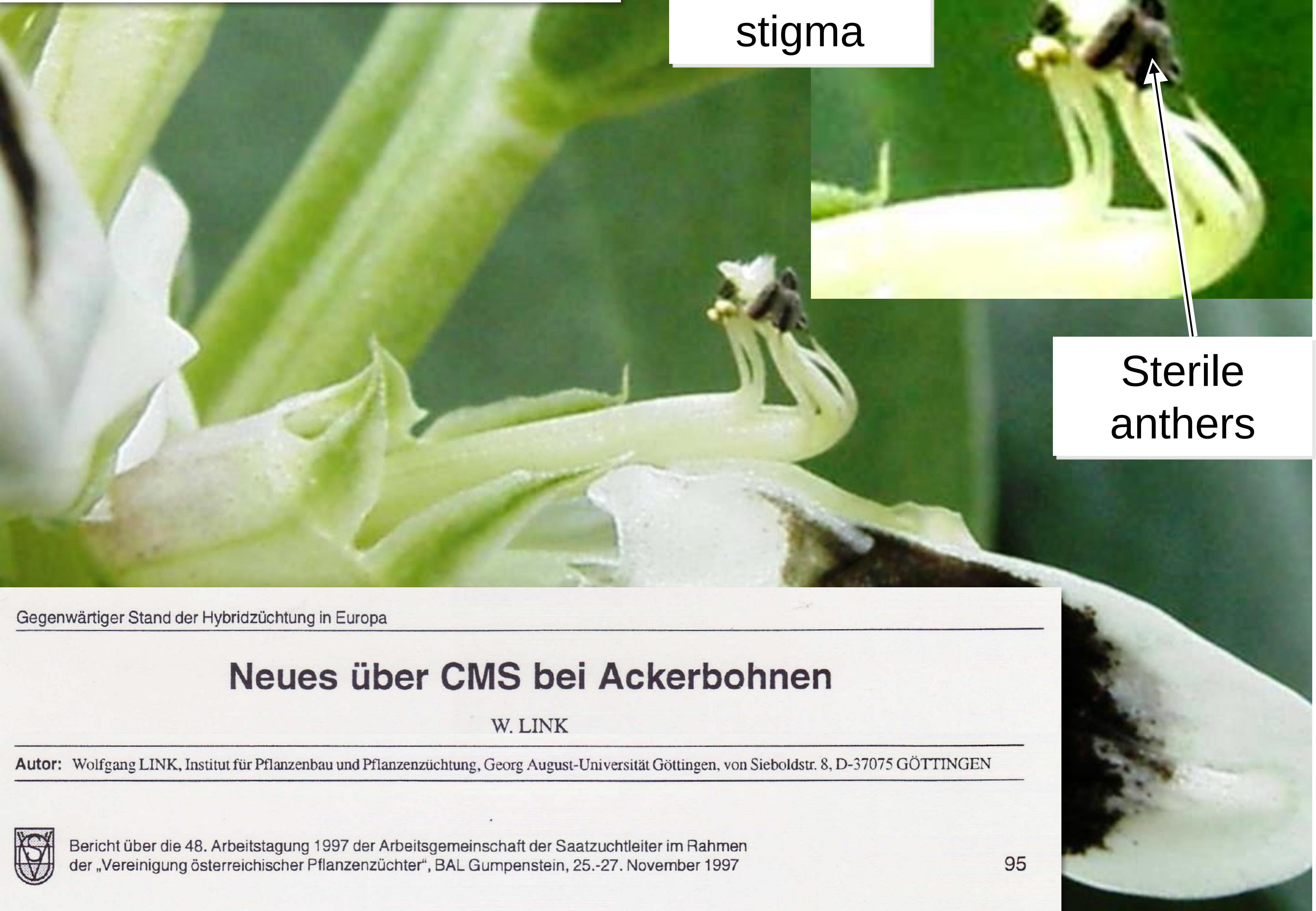
PEOPLE PUBLICATIONS RESEARCH TEACHING NEWS & ANNOUNCEMENTS HISTORY OF THIS CHAIR AND DIVISION

➢ Line breeding
Cultivars created by controlled/natural selfing as pure, homozygous inbred lines. Take the ‘best’ genotype, yet, do not exploit heterosis

➢ Hybrid breeding
Cultivars created by controlled crossing between two distinct, genetically different genotypes (typically inbred lines)

➢ Population breeding
Cultivars are non-inbred populations with a high level of heterozygosity and heterogeneity. A specific type is the so-called synthetic cultivar (synthetic variety). Seed of such cultivars is produced via “open” pollination, i.e., natural random mating

Phenotype of CMS199



Link, Ederer, Gumber, and Melchinger, 1997: Detection and characterization of two new CMS systems in faba bean (*Vicia faba*). Plant Breeding 116: 158 - 162.

Gegenwärtiger Stand der Hybridzüchtung in Europa

Neues über CMS bei Ackerbohnen

W. LINK

Autor: Wolfgang LINK, Institut für Pflanzenbau und Pflanzenzüchtung, Georg August-Universität Göttingen, von Sieboldstr. 8, D-37075 GÖTTINGEN

Bericht über die 48. Arbeitstagung 1997 der Arbeitsgemeinschaft der Saatzuchtleiter im Rahmen der „Vereinigung österreichischer Pflanzenzüchter", BAL Gumpenstein, 25.-27. November 1997 95

Little was published on CSM in faba bean in all this time

frontiers in
PLANT SCIENCE

ORIGINAL RESEARCH ARTICLE
published: 07 May 2013
doi: 10.3389/fpls.2013.00128

Mitochondrial genome sequence of the legume *Vicia faba*

Valentine Negruk *

Biotechnology Research Lab, Miami Dade College, Miami, FL, USA

Eur. J. Biochem. *127*, 129 – 135 (1982)
© FEBS 1982

Mitochondrial Modifications Associated with the Cytoplasmic Male Sterility in Faba Beans

Marc BOUTRY and Michel BRIQUET

Centre de l'Hérédité Cytoplasmique, Laboratoire d'Enzymologie, Université Catholique de Louvain

(Received May 21 / June 29, 1982)

Isolated mitochondria of faba beans carrying two different determinisms of the cytoplasmic male sterility (cytoplasms 447 and 350) have been compared to fertile lines.

Journal of General Virology (1998), **79**, 2349–2358. Printed in Great Britain

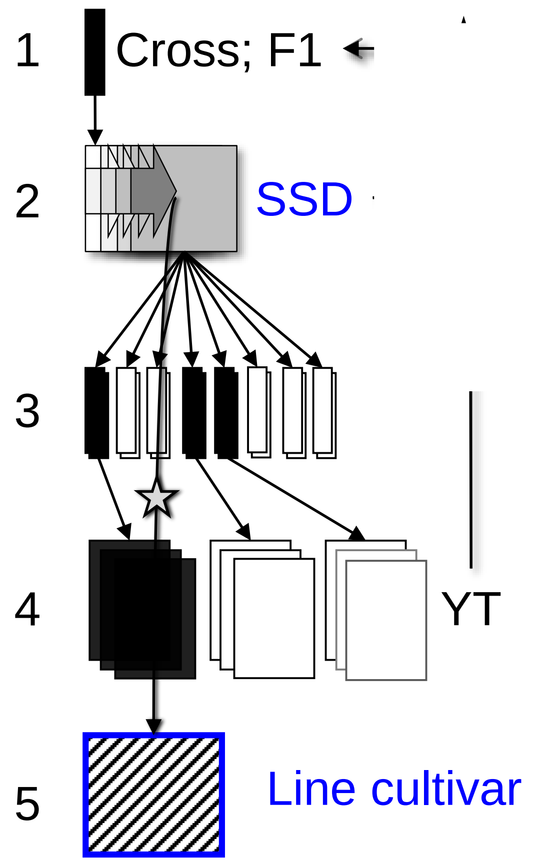
Nucleotide sequence, genetic organization and expression strategy of the double-stranded RNA associated with the '447' cytoplasmic male sterility trait in *Vicia faba*

Pierre Pfeiffer

CMS447. D.A. Bond, PBI UK.	>1957
CMS350. P. Berthelem. INRA F.	>1960
CMS297. W. Link, Hoh'heim D.	>1992
CMS199. W. Link, Hoh'heim D.	>1992

Breeding Scheme for faba bean.

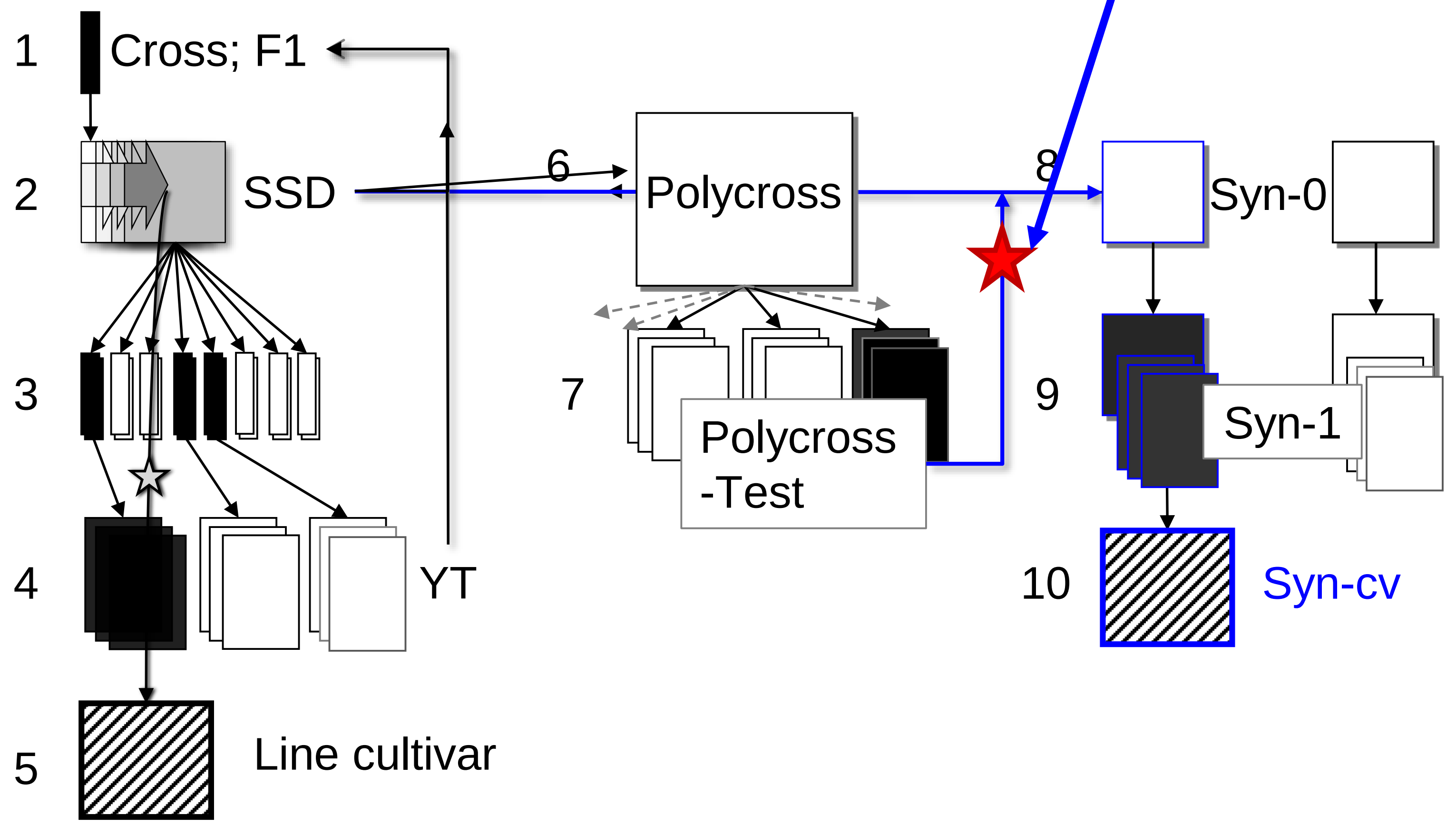
(1) Crosses. (2) SSD until about F6. (3) Multiply F6 individuals in open field & phenotypic selection. (4) Test open pollinated offspring for yield (YT), identify best SSD lines as new parents. (5) Release line cultivar



Adhikari, K.N., H. Khazaei, L. Ghaouti, F. Maalour, A. Vandenberg, W. Link, D.M. O'Sullivan, 2021: Conventional and molecular breeding tools for accelerating genetic gain in faba bean (*Vicia faba* L.). Frontiers in Plant Science 12: 744259. DOI: 10.3389/fpls.2021.744259.

Breeding Scheme for inbred-line based synthetics in faba bean.

Select. Yet ... how to account for inbred line •per se performance L, inbred line •GCA effect, size of •heterosis (μ_C -μ_L) in connection to •number k of components, degree X of •cross-fertilization of individual components, ... further performance and heterosis-related factors?



Adhikari, K.N., H. Khazaei, L. Ghaouti, F. Maalour, A. Vandenberg, W. Link, D.M. O'Sullivan, 2021: Conventional and molecular breeding tools for accelerating genetic gain in faba bean (*Vicia faba* L.). Frontiers in Plant Science 12: 744259. DOI: 10.3389/fpls.2021.744259.

Parameter	Random mating (Wright, 1973; Becker, 1988)
$\mu_{Syn}(k)$	$\mu_L + (1 - \frac{1}{k}) \cdot (\mu_C - \mu_L)$
GVA $(k)_i$ General Varietal Abiliy	$\frac{1}{k^2} \cdot L_i +$ $\frac{1}{k} \cdot (1 - \frac{1}{k}) \cdot 2\, GCA_i$
SVA $(k)_{ij}$ Sp. varietal ability	$\frac{1}{k^2} \cdot 2SCA_{ij}$

L per se performance of candidate lines
C performance of hybrids
X degree of cross-fertilization
GCA General Combining Ability (~½ BV)
SCA Specific combining ability (~dominance deviation)
k = number of components per cultivar
P = paternal outcrossing success

Theoretical and Applied Genetics 43, 79—82 (1973)

The Selection of Parents for Synthetic Varieties of Outbreeding Diploid Crops

A. J. WRIGHT

Plant Breeding Institute, Cambridge (England)

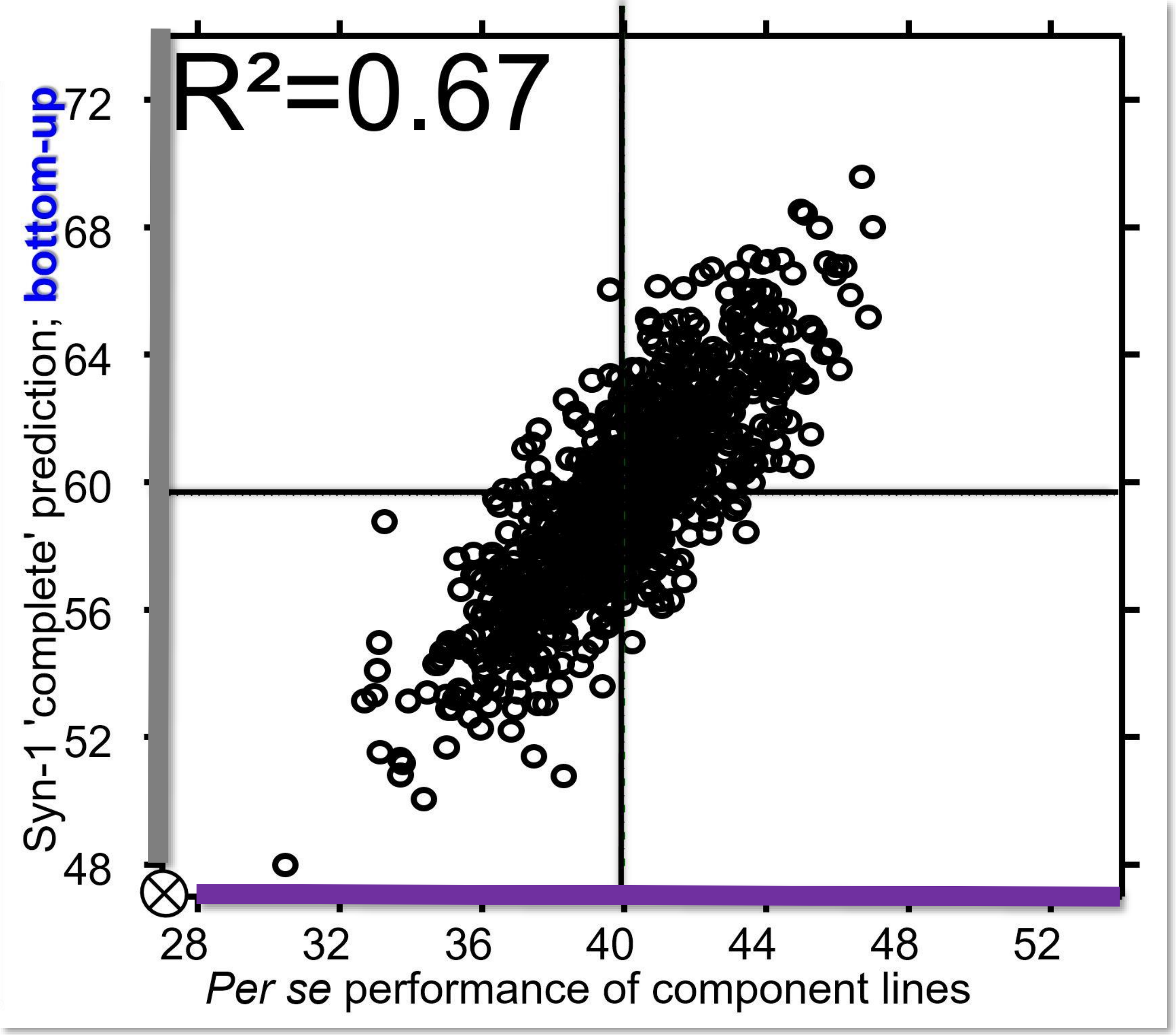
Summary. As a criterion for the selection from a population of individuals with a high potential as parents of synthetic varieties, the general varietal ability of an individual is defined as the mean expression of all possible synthetics of a given size(s) having this plant as a common parent. Using known expressions for the prediction of the performance of advanced generations of diploid synthetic varieties, general varietal ability is expressed in terms of the F_1 and I_1 progenies of the plants under test, and is found to be a simple function of the polycross (g.c.a.) and inbred progeny means, where the contribution of the inbred progeny varies according to n and s. The implications and use of such a progeny test in the breeding of out-pollinating crops is discussed.

Parameter	Random mating (Busbice (1969,1970; Becker, 1988)	Partial Allogamy (Link & Ederer, 1993)
$\mu_{Syn}(k)$	$\mu_L + (1 - \frac{1}{k}) \cdot (\mu_C - \mu_L)$	$\mu_L + \mu_X \cdot (1 - \frac{1}{k}) \cdot (\mu_C - \mu_L)$
$GVA\ (k)_i$ General Varietal Abiliy	$\frac{1}{k^2} \cdot L_i$ + $\frac{1}{k} \cdot (1 - \frac{1}{k}) \cdot 2\ GCA_i$	$\frac{1}{k} \cdot [\, 1 - \mu_X (1 - \frac{1}{k})] \cdot L_i$ + $\frac{1}{k} \cdot \mu_X (1 - \frac{1}{k}) \cdot 2GCA_i$ + $\frac{1}{k} \cdot X_i \cdot (1 - \frac{1}{k})\, [(\mu_C + GCA_i) - (\mu_L + L_i)]$
$SVA\ (k)_{ij}$ Sp. varietal ability	$\frac{1}{k^2} \cdot 2SCA_{ij}$	$\frac{1}{k^2} \cdot (X_i \cdot GCA_j + X_j \cdot GCA_i)$ + $\frac{1}{k^2} \cdot (2\mu_X + X_i + X_j) \cdot SCA_{ij}$

Partial Allogamy
& Variation of Paternal Success **P**
(Brünjes & Link, 2017)

Parameter	Random mating (Busbice (1969,1970; Becker, 1988)	Partial Allogamy (Link & Ederer, 1993)	Partial Allogamy & Variation of Paternal Success **P** (Brünjes & Link, 2017)
$\mu_{Syn}(k)$	$\mu_L + (1 - \frac{1}{k}) \cdot (\mu_C - \mu_L)$	$\mu_L + \mu_X \cdot (1 - \frac{1}{k}) \cdot (\mu_C - \mu_L)$	$\mu_L + \mu_X \cdot (1 - \frac{1}{k}) \cdot (\mu_C - \mu_L)$
$GVA(k)_i$ General Varietal Abiliy	$\frac{1}{k^2} \cdot L_i +$ $\frac{1}{k} \cdot (1 - \frac{1}{k}) \cdot 2\,GCA_i$	$\frac{1}{k} \cdot [1 - \mu_X (1 - \frac{1}{k})] \cdot L_i +$ $\frac{1}{k} \cdot \mu_X (1 - \frac{1}{k}) \cdot 2GCA_i +$ $\frac{1}{k} \cdot X_i \cdot (1 - \frac{1}{k}) [(\mu_C + GCA_i) - (\mu_L + L_i)]$	$\frac{1}{k} \cdot [(\mu_X + X_i) \cdot \mathbf{P_{ii}}] \cdot \mu_L +$ $\frac{1}{k} \cdot [1 - \mu_X \cdot (1 - \frac{1}{k})] \cdot L_i +$ $\frac{1}{k} \cdot [(\mu_X + X_i) \cdot \mathbf{P_{ii}}] \cdot L_i +$ $\frac{1}{k} \cdot \mu_X \cdot [(1 - \frac{1}{k}) \cdot 2GCA_i] +$ $\frac{1}{k} \cdot [X_i \cdot (1 - \frac{1}{k}) \cdot (\mu_C + GCA_i - \mu_L - L_i)] +$
$SVA(k)_{ij}$ Sp. varietal ability	$\frac{1}{k^2} \cdot 2SCA_{ij}$	$\frac{1}{k^2} \cdot (X_i \cdot GCA_j + X_j \cdot GCA_i) +$ $\frac{1}{k^2} \cdot (2\mu_X + X_i + X_j) \cdot SCA_{ij}$	$\frac{1}{k^2} \cdot (X_i \cdot GCA_j) +$ $\frac{1}{k} \cdot [(\mu_X + X_i) \cdot \mathbf{P_{ij}} \cdot (\mu_C + GCA_i + GCA_j)]$

Prediction of synthetic cultivars (k=4; Syn-1) based on per se performance alone



Parameter from own data and literature

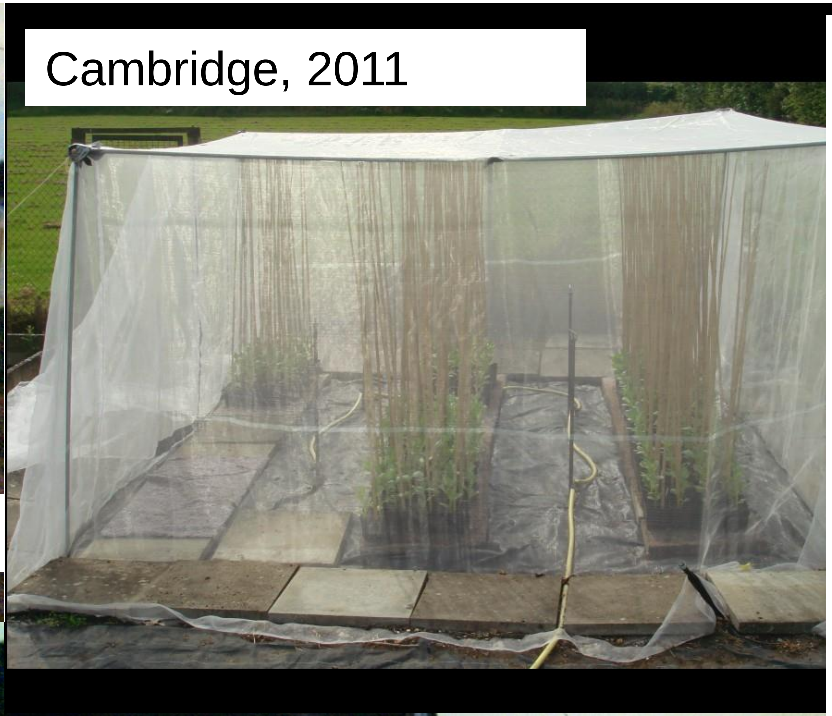
X-axis: Predict performance in Syn-1 from inbred line *per se* performance alone

Y-axis: ‚True‘ performance (i.e. predict including variation of all parameters).

Judith Reese, MSc thesis, 2022:
Breeding method simulations to predict partially allogamous, synthetic faba bean cultivars from their parental components (number of compo-nents, *per se* performance, GCA, degree of cross-pollination X, paternal success P)

How much does paternal outcrossing success P explain when prediction Syn-1 (k=4)?	
.... added to *per se*, GCA, X	11.10%
... used as only parameter	14.69%

Rennes, 1989



Cambridge, 2011

Hohenlieth, 1988

Dijon, 1987

To assess *per se* performance of inbred lines, you need purely selfed seed ... from controlled self-fertilization.

Employing cages is the first step to become a serious faba bean researcher. Separate the beans from the bees!

Isolation cages. Needed to control pedigree (on paternal side).

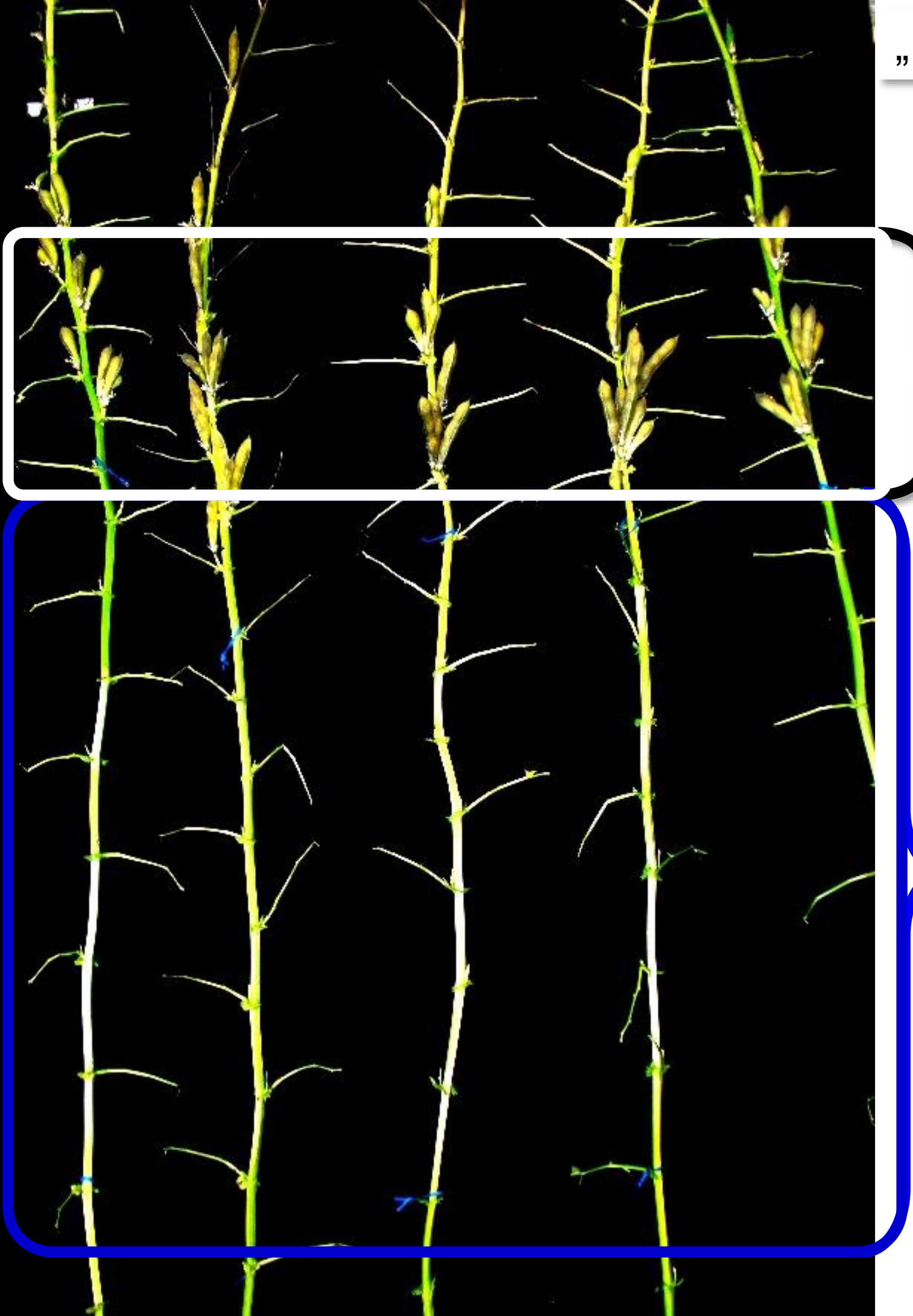
One reason why breeding of lentils, pea, soy ... is easier than breeding of faba beans

Isolation cage: to keep honey bees and bumble bees out, to avoid natural cross-pollination

David Bond

Faba bean breeding nursery near Khartoum, Sudan.

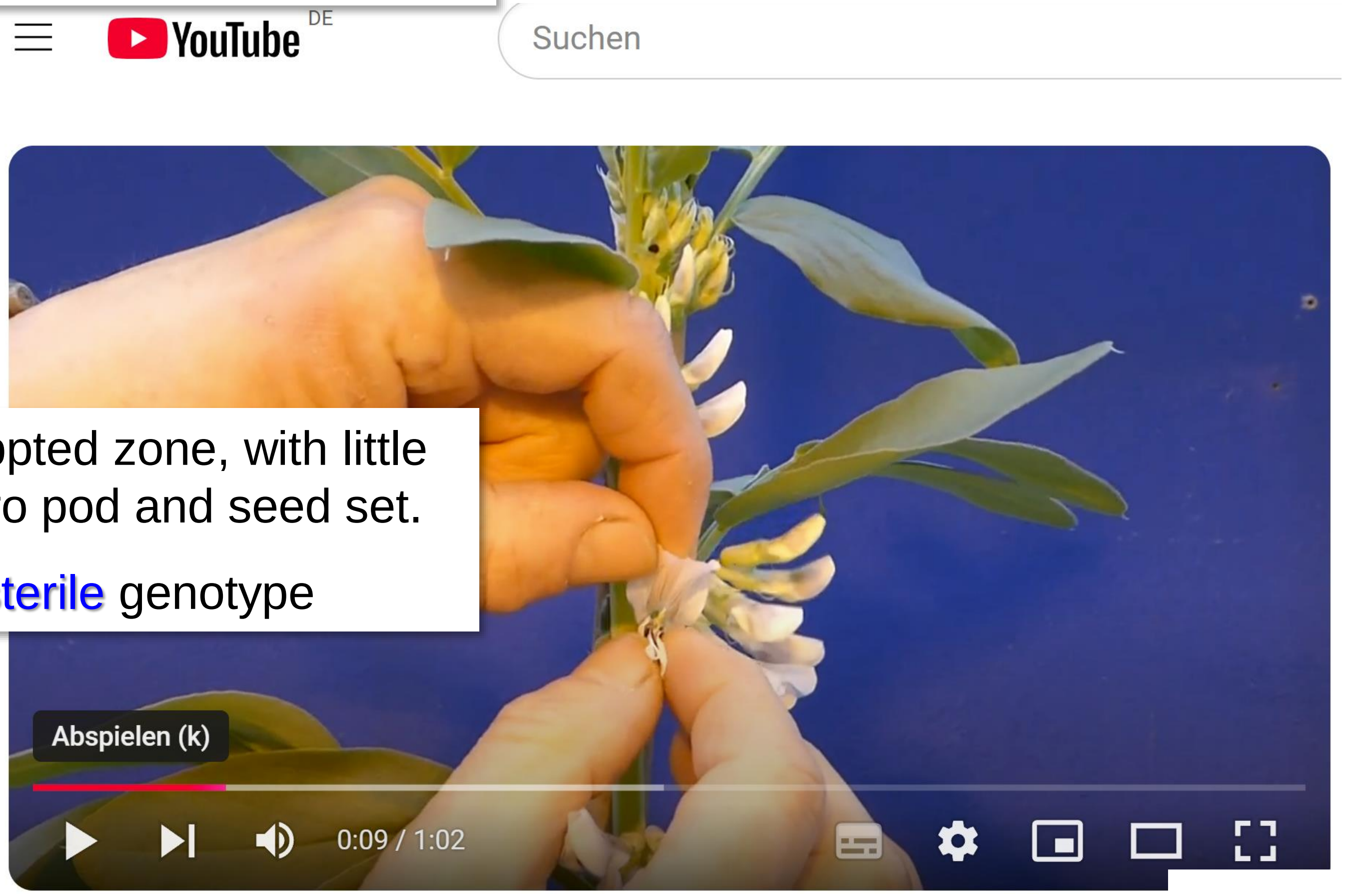
„No pollinators here? What a disappointment, I'll stay barren! "



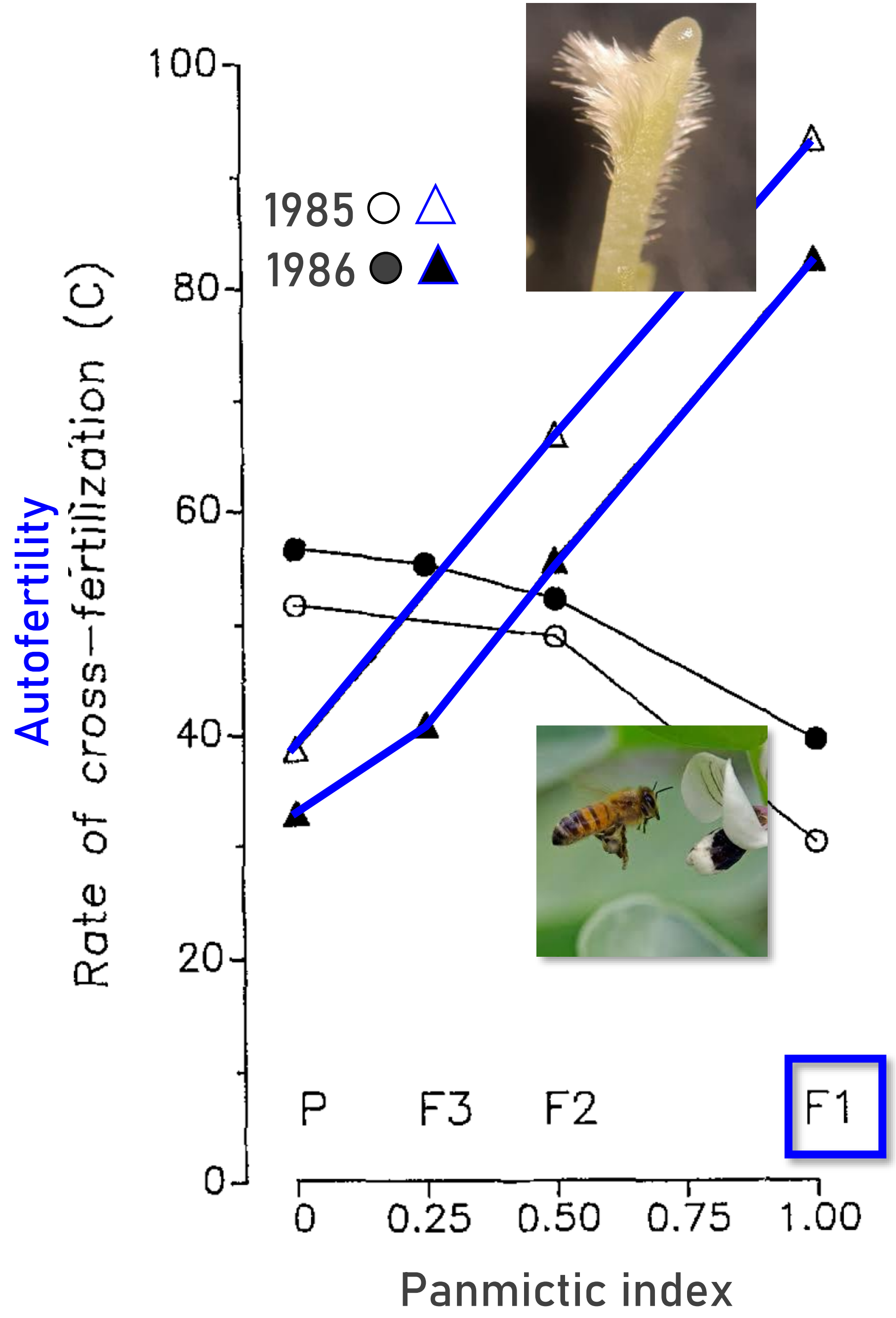
Tripped zone, shows pod and seed set

Untripped zone, with little or zero pod and seed set.

Autosterile genotype



Tripping of faba beans



Hybrids tend to be autofertile; they self-fertilize and thus set seed spontaneously (un-tripped), whereas inbreds tend towards the opposite; ‚stubborn‘ ;-)

Autofertility and rate of cross-fertilization: crucial characters for breeding synthetic varieties in faba beans (*Vicia faba* L.)

W. Link

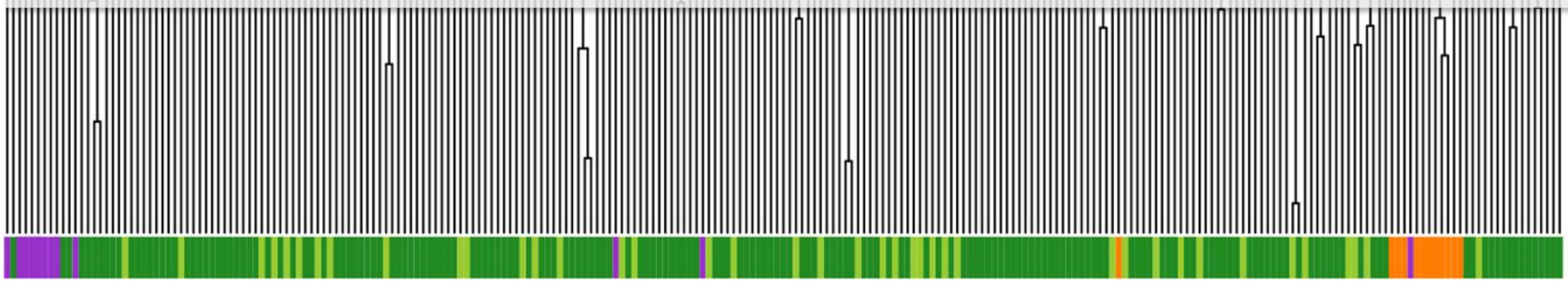
Institute for Plant Breeding, Seed Science and Population Genetics, University of Hohenheim, Postfach 70 05 62, D-7000 Stuttgart 70, FRG

Received November 21, 1989; Accepted November 30, 1989
Communicated by A. R. Hallauer

Theor Appl Genet (1990) 79:713–717

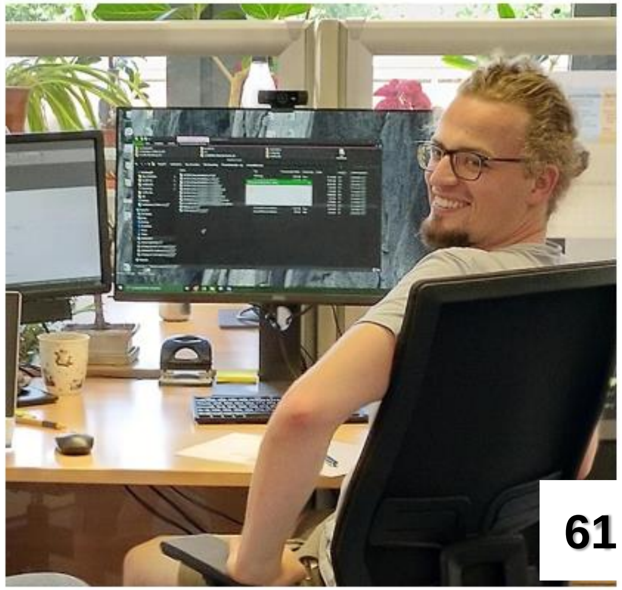
We combine application of Quantitative Genetics to Phenotypic and Pedigree data with (sending leaves to a service provider at Gatersleben and) analysing data from DOS' SNP array (Vfaba_v2 Axiom SNP array) and from KASP analyses ☺.

Dissertation project of Alex Windhorst on GWAS and Genomic Prediction of frost tolerance and winter hardiness in faba bean



Rogers Distance; UPGMA; Color bar according to Set and subset definition

Vfaba_v2 Axiom SNP array 60k

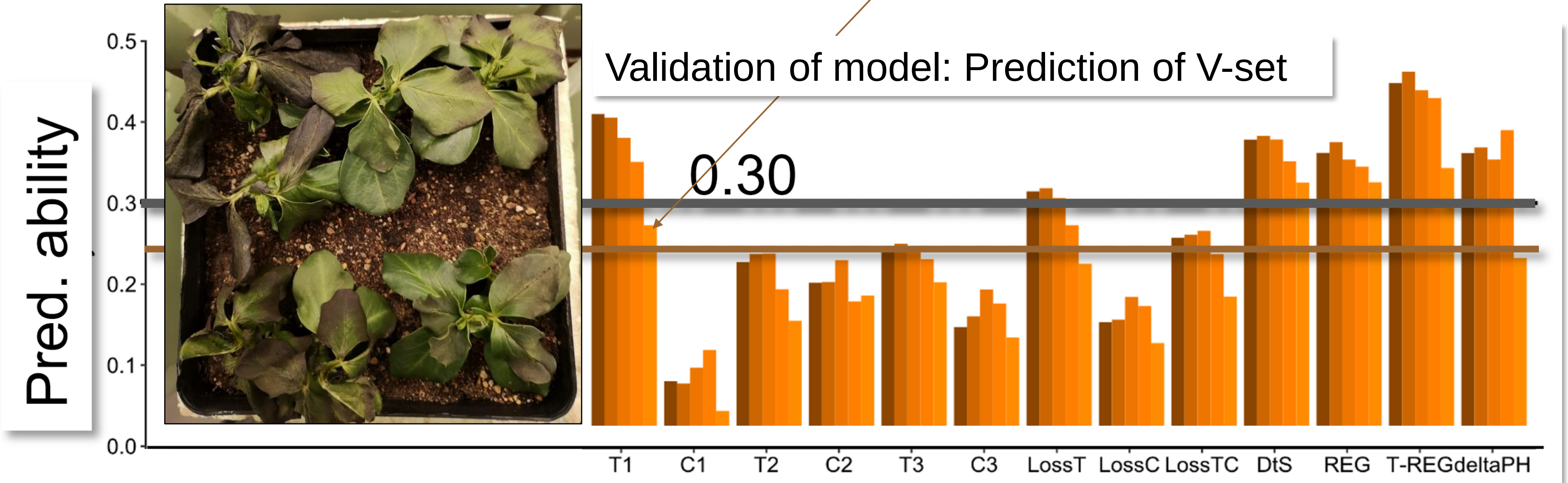


Genomic Prediction of (late-frost) symptoms in frost chamber (GBLUP in R; rrBLUP package, G matrix VanRaden 2008). Training set 185 inbred lines: 5 experiments à 2 reps. Validation set 64 inbred lines; 7 experiments à 3 reps. 0.63 < h^2 < 0.95

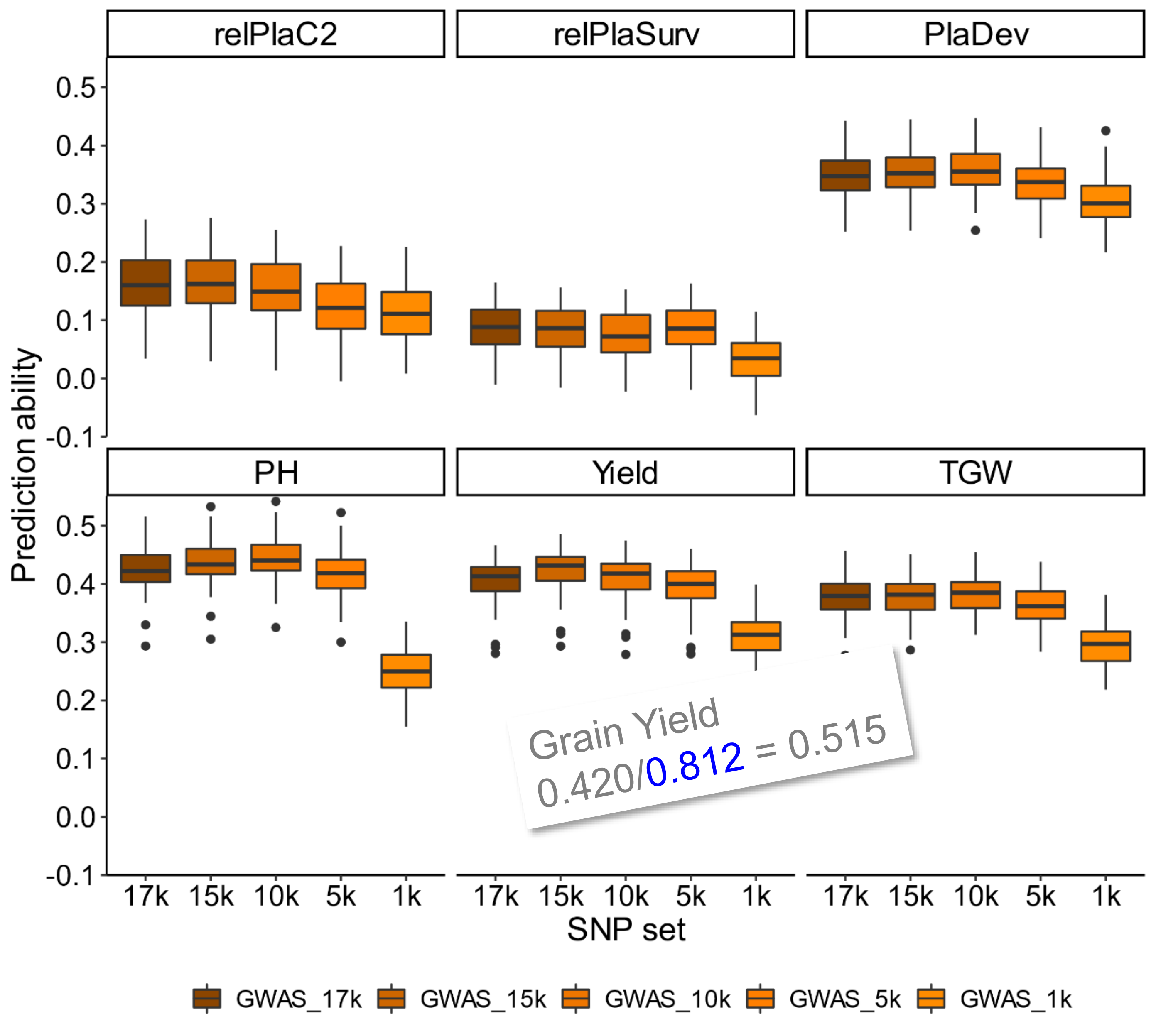
Brownish line: Sign. threshold of Prediciton ability

5 SNP set sizes: 17k – 15k ~ same predict. ability; at 1k, however, it drops off !

Reasonable high pred. ability in this hard validation setting.



Genomic Prediction of field-based traits. Training set 185 inbred lines. Historical field data (2005-2022; E=17); 0.55 < h^2 < 0.92. 5-fold cross-validation.



Winter Hardiness-related field-assessed traits and Yield-related traits.

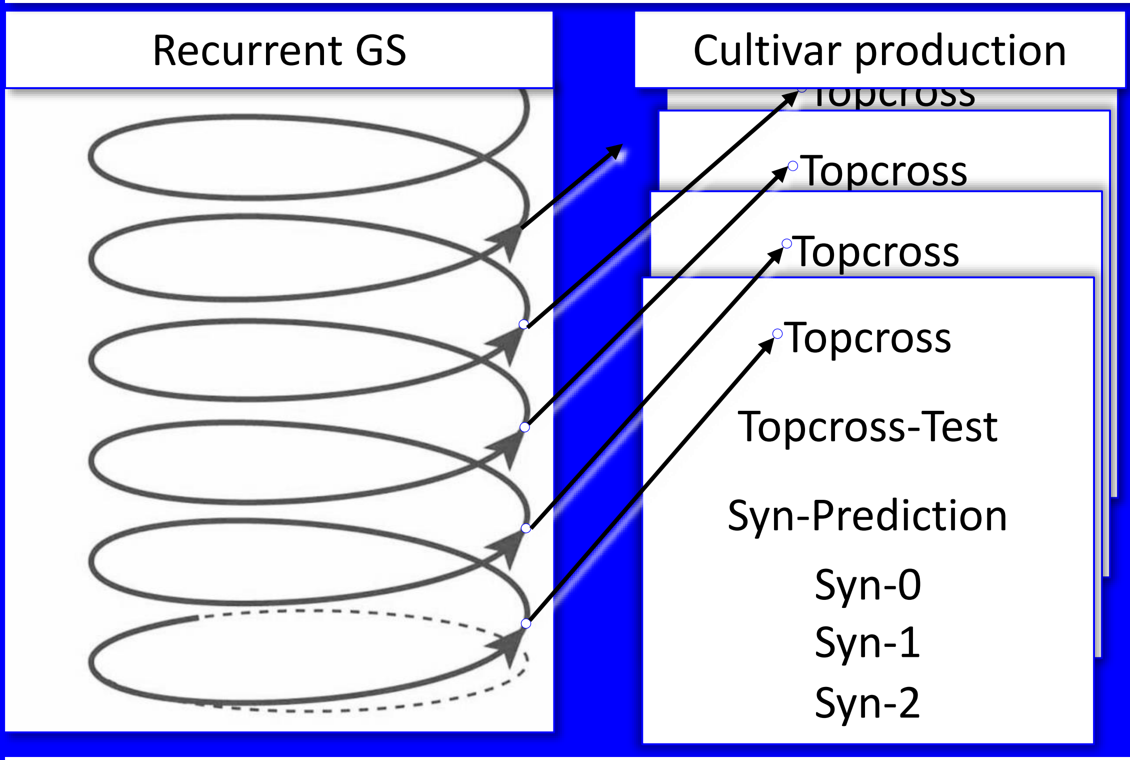
rePlaC2 h^2=0.740
Relative plant number count (after winter/sowing)

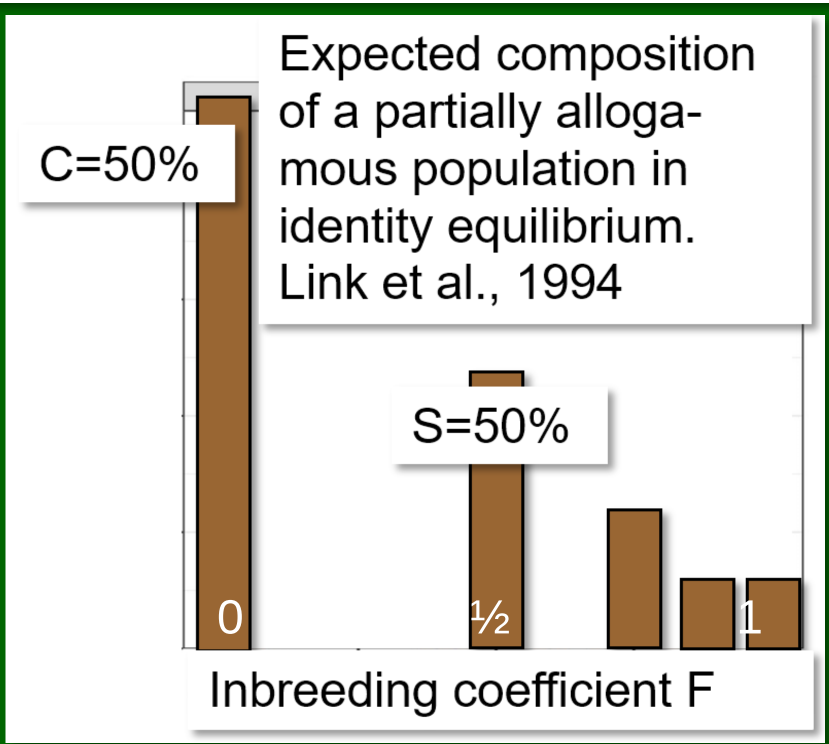
relPlaSurv h^2=0.555
Relative plant survival (after winter/before winter)

PlaDev h^2=0.547
Plant(plot) development score after winter

Plant height PH h^2=0.912
Yield h^2=0.812
TGW h^2=0.936

Abo-Direkt. Combine Gaynor et al., 2017 & Link et al., 1994; Link, 2013.
New Breeding paradigm and GS to substitute missing DH technology.





Published online August 3, 2017

RESEARCH

A Two-Part Strategy for Using Genomic Selection to Develop Inbred Lines

R. Chris Gaynor, Gregor Gorjanc, Alison R. Bentley, Eric S. Ober, Phil Howell, Robert Jackson, Ian J. Mackay, John M. Hickey*

Vortr. Pflanzenzüchtg. 30, 201-230 (1994)

Zuchtmethodische Entwicklungen - Nutzung von Heterosis bei Fababohnen

W. Link[1], W. Ederer[2] und E. von Kittlitz[1]

[1]Universität Hohenheim (720), Landessaatzuchtanstalt

[2]Universität Hohenheim (350),
Institut für Pflanzenzüchtung, Saatgutforschung und Populationsgenetik

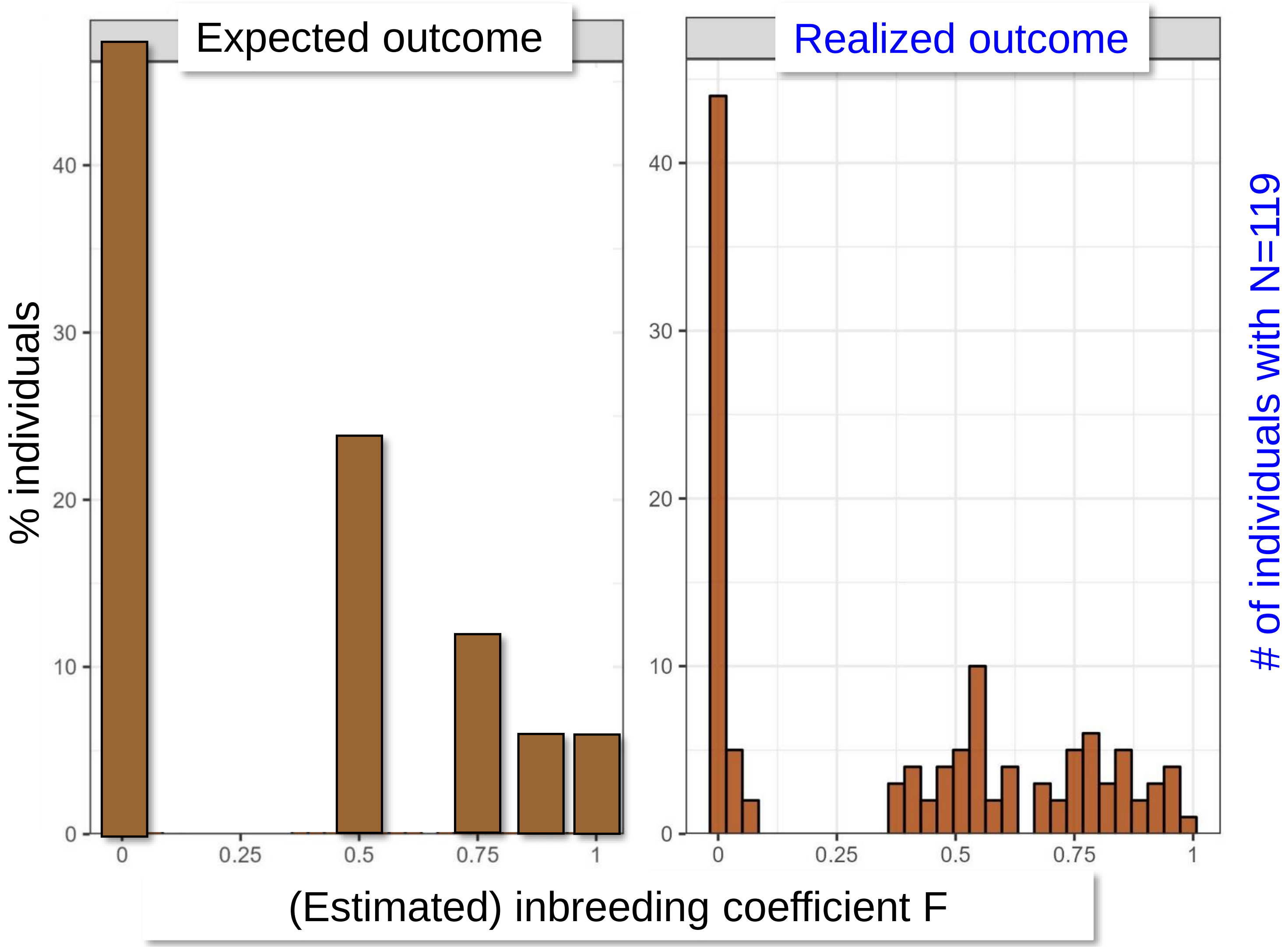
D-70593 Stuttgart

Dissertation project of Henri Laugel ‚Abo-Direkt‘. Make use of *à priori* available inbred individuals in faba bean population instead of DH technology

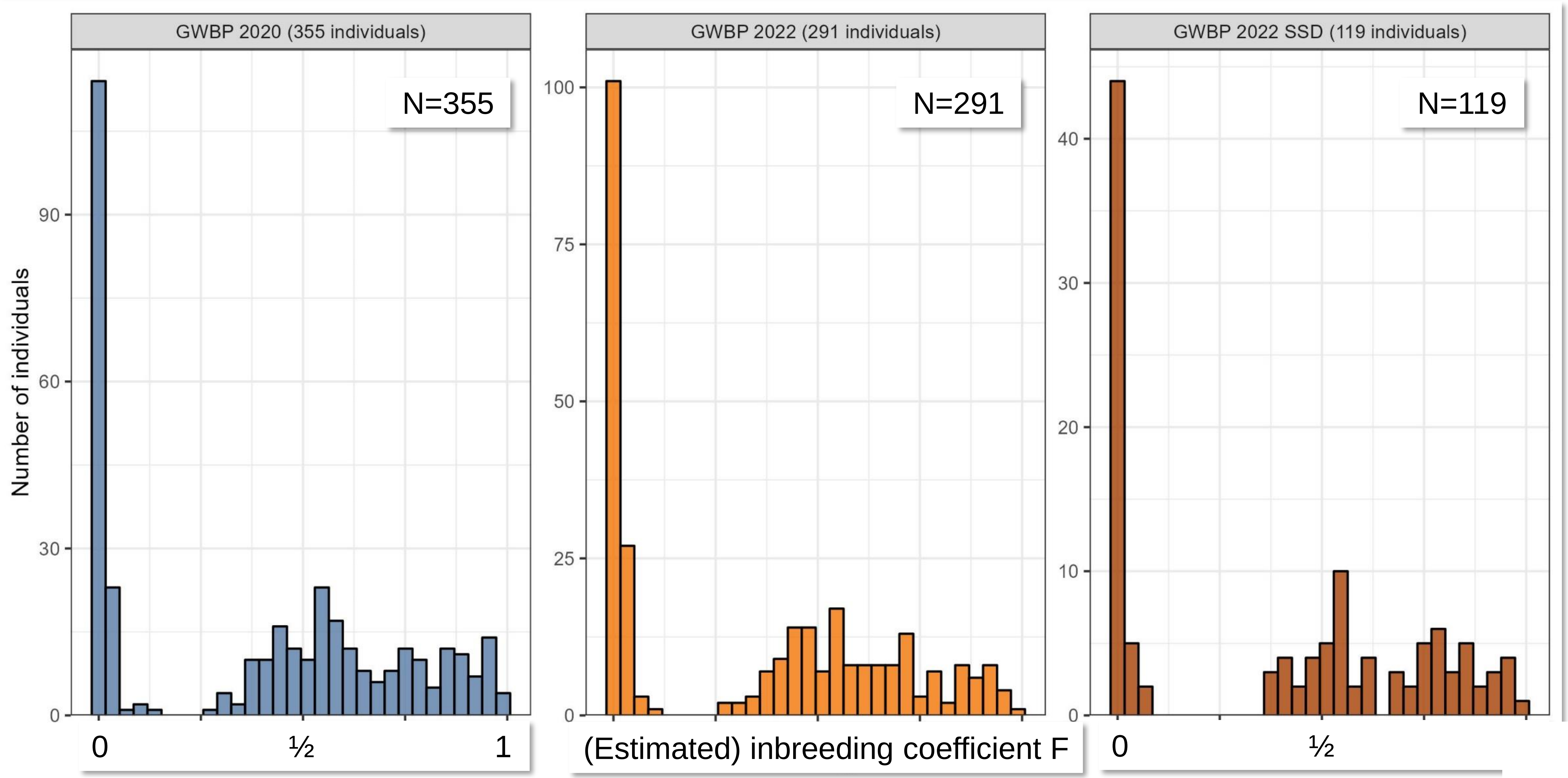
(1) Identify highly homozygous indiviudals in population *via* markers
(2) Estimate their GEBV for agronomic traits (model trained from historical data); select accordingly
(3) Propagate (cage) most promising inbred individuals to have seed for upcoming plot-based field test
(4) Field-test inbred lines as Poly/Topcross progenies (~GVA)
(5) Predict synthetics, field test most promising ones from joining ex-trial seed …

Famous Göttingen Winter Bean Population under natural selection; in isolation by distance (open pollinator access)

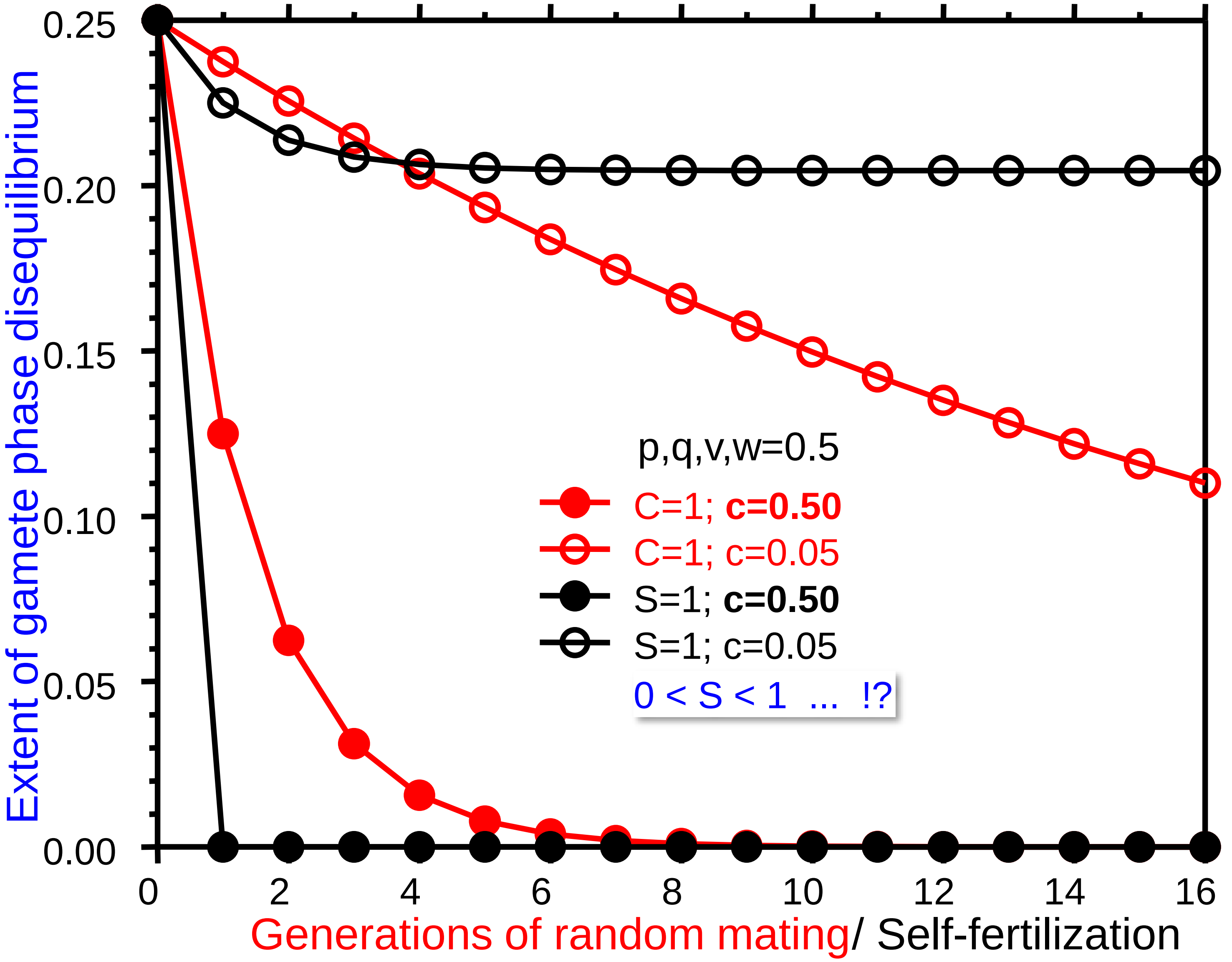
Test hypotheses about existence and share of inbreeding cohorts in partial allogamous faba bean GWB population. Estimate F of individuals from ~17.000 SNP (Vfaba_v2 Axiom SNP array; 60k).



Henri Laugel; ‚Abo-Direkt‘. Experimental finding on the distribution of estimated inbreeding coefficients F in three versions of the Famous Göttingen WB population.



A further task in Abo-Direkt. LD between SNP and focal locus and allele is crucial for marker-assisted work. The literature is divided on LD decay in partial allogamy



Golding and Strobeck, 1980. Genetics 94: 777

Weir and Cockerham 1973. Gen. Res., Camb. 21, 247

Karlin 1969. Gordon and Breach, New York

Vargas and Castillo 2001. IMA J Math Apl Med Biol 18, 327

Begin not ‘Diallel’ ?!

Begin not F = [S/(2-S)] ?!

Frequency of double heterozygotes not $(1-F)^2$ because of ‘Identity Disequilibrium’ ?!

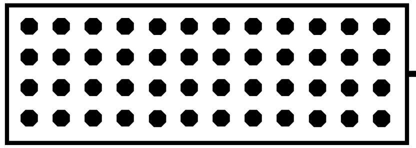
Ali et al., 2016; $R^2=0.0077$

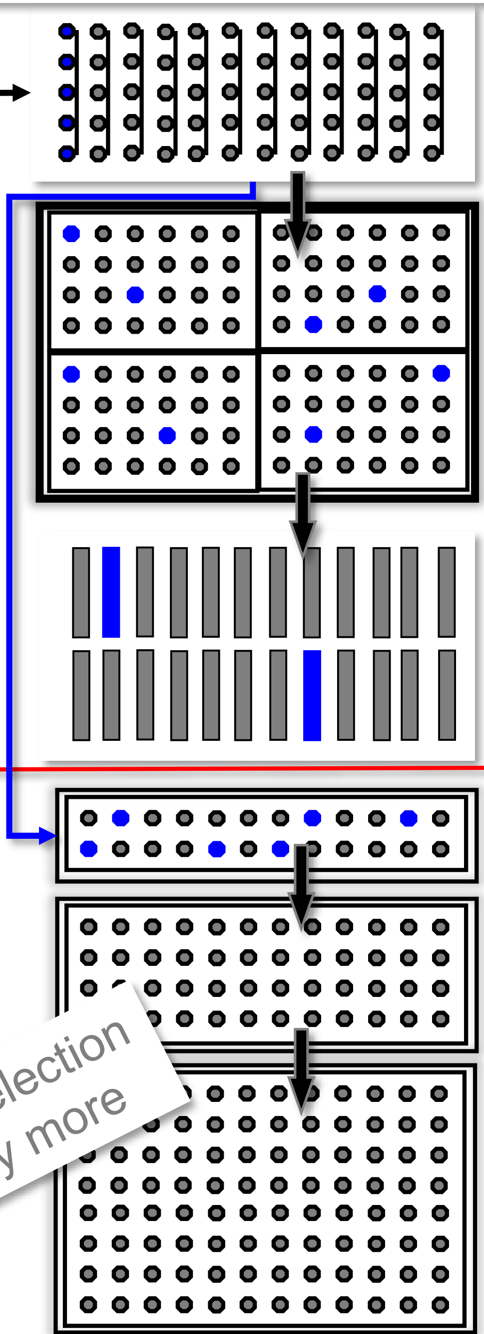
Two awards for the Göttingen team at GPZ conference 2024

…

Assumptions* to simulate 3200 inbred lines and their hybrids; to predict bottom-up synthetics in generation Syn-1 and Syn-∞			
Parameter		Mean	Standard Deviation
Degree of cross-fertilization		50.0%	8.0%
Paternal outcrossing success*	N=4	25.0%	8.6%
Per se yield of inbred lines		40 dt ha^{-1}	5.0 dt ha^{-1}
GCA (yield) of inbred lines		2.5 dt ha^{-1}	2.5 dt ha^{-1}
SCA for pairs of inbred lines		0.0 dt ha^{-1}	0.0 dt ha^{-1}
Yield of F1-hybrids		90 dt ha^{-1}	7.1 dt ha^{-1}

Basic scheme of breeding a synthetic cultivar (for outcrossers, needless to say)





Maintain selected clones or inbred lines

Take clones or extract inbred lines as candidates of synthetic cultivars‘s components

Polycross with candidate components

Polycross-Test. Estimate GCA of candidate components

Seed harvested from Polycross-Test (GCA) is not used as seed again.

Select. Go back to the maintained candidate components. Create generation Syn-0.

Grow random-mated offspring from Syn-0 as generation Syn-1.

No selection any more

Grow random-mated offspring from Syn-1 as generation Syn-2.