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Rudolf Mansfeld and Plant Genetic Resources

Proceedings of a symposium dedicated
to the 100th birthday of Rudolf Mansfeld,
Gatersleben, Germany, 8-9 October 2001

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Preface

In October 2001, the Institute of Plant Genetics and Crop Plant Research (IPK) in Gatersleben, Germany, organised an international scientific symposium commemorating the centenary of RUDOLF MANSFELD, who was born on January 17, 1901. The symposium, entitled "Rudolf Mansfeld and Plant Genetic Resources", and dedicated to his life's work and scientific legacy was co-organised by the Genetic Resources Section of the Gesellschaft für Pflanzenzüchtung (GPZ, Society for Plant Breeding), and the Gemeinschaft zur Förderung der Kulturpflanzenforschung in Gatersleben e.V. (Society for the Advancement of Cultivated Plant Research).

Professor RUDOLF MANSFELD worked in Gatersleben between 1946 and 1960, and was the former head of the Department of "Systematik und Sortiment" (Systematics and World Collection of Cultivated Plants) of the former Institute of Cultivated Plant Research. He was a plant taxonomist from the famous Berlin school of ADOLF ENGLER, and he developed principles for the classification of cultivated plants. With this pioneering work, and with his "Provisional list of agricultural and horticultural species of cultivated plants" (MANSFELD 1959), he laid the foundations for many of IPK's current research activities. In 2001, the third edition of this inventory and the first one in English, with information on 6,100 plant species, was published as "Mansfeld's Encyclopedia" in six volumes (HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH 2001), and the "Mansfeld Database", an Internet database developed from the Encyclopedia, was released to the public (http://mansfeld.ipk-gatersleben.de/mansfeld/). MANSFELD also created the scientific basis for the establishment and preservation of extensive collections of cultivated plants, referred to as genebanks today. As a complement to the living (primarily seed) collections, he created reference collections of herbarium specimens, seed and spike samples, which are indispensable today for documentation and comparison purposes as well as for identity checks of the genebank material (e.g., after multiple regeneration cycles) and for scientific investigations. During the last years of his life, he started to evaluate the collections in cooperation with other research institutions and breeders, mainly with respect to resistance characteristics aligned to breeders' interests. This evaluation process was continued later by his successors on a large scale. For more information about RUDOLF MANSFELD's scientific work, see also the contributions by P. HANELT and K. HAMMER here, and the list of MANSFELD's publications (DANERT 1962), which can also be found on the MANSFELD website.

The commemorative symposium took place in Gatersleben on 8 and 9 October 2001, and in English. The programme included 22 invited lectures and 31 poster presentations. Among the 85 participants, 57 came from Germany (including 17 from IPK), 20 from ten European countries, as well as eight from non-European countries, among them scholarship holders of the long-term training course on plant genetic resources organised at IPK by the German Foundation for International Development (DSE).

The Symposium was structured in five sections:

Welcome and introduction

A. GRANER, head of the Genebank Department, welcomed the participants and outlined the present structure of this Department and its fields of work. P. HANELT (Gatersleben) gave personal recollections of MANSFELD, as a highly-esteemed, constructively-critical scientist, but also a modest and humorous person who liked personal conversation. K. HAMMER (Witzenhausen, Germany) highlighted MANSFELD's characteristic contributions to research into cultivated plants, e.g., the evaluation of the collections documented in a series of 29 publications on resistance studies of the Gatersleben barley and wheat collections, which was aimed at supporting plant breeding. The influence of MANSFELD in shaping plant genetic resources research was illustrated by presentations from four speakers. A contribution from J. HAWKES (Birmingham, UK, read out by R.N. LESTER) recalled memories and personal encounters with N.I. VAVILOV and O. FRANKEL; K. PISTRICK (Gatersleben) reported on the present "Mansfeld's Encyclopedia" from a personal perspective, and H. KNÜPFFER outlined the national and international context of the "Mansfeld Database". J. ENGELS (IPGRI, Rome, Italy) concluded this section with the presentation of a "Compendium on Plant Genetic Resources" planned by the International Plant Genetic Resources Institute.

Taxonomy of cultivated plants

J. OCHSMANN (Gatersleben) explained how the "International Code of Botanical Nomenclature" is necessarily more or less rigid and obligatory for wild species and higher taxa, while taxonomy of cultivated plants is not only expected to meet scientific hierarchical and evolutionary principles, but also to be "user-friendly" for non-taxonomists growing domesticated cultivars, and it should take more account of genetics, ethnology and geography. The present "International Code of Nomenclature for Cultivated Plants" is not always appropriate for classifying germplasm collections. Theoretical and practical problems resulting from this were discussed by C. JEFFREY and T. SMEKALOVA (both St. Petersburg, Russia), exemplified by cases from the Compositae, Cucurbitaceae (JEFFREY) and Leguminosae (SMEKALOVA). An interesting picture of the obviously multiple domestication centres of *Phaseolus vulgaris* in Central and South America was sketched by B. PICKERSGILL (Reading, U.K.) on the basis of the geographical distribution of DNA markers.

Ethnobotany of plant genetic resources

This section was devoted to the co-evolution of people and plants. A. SZABÓ T. (Veszprém, Hungary) pursued the development of cultivated plants in connection with the migration to southeastern Europe of Magyar peoples from East and Middle

Asia. M. Chauvet (Montpellier, France) gave an introduction to his “Inventory of Food Plants in France”, a book planned to describe about 770 plant species with regard to their botany, history and use. W. Podyma (Radzików, Poland) reported on exploration and collection of landraces in the Carpathians in southeast Poland, where up to two-thirds of the formerly existing diversity has been lost in this region due to economic changes between 1978 and 1995. Growing interest in biodiversity and consciousness of cultural identity were illustrated by Th. Gladis (Witzenhausen/Bonn, Germany), who showed the wealth of cultivars of crop species grown in small gardens around Bonn by immigrants from the Ukraine, Turkey and elsewhere.

Diversity of cultivated plants induced by cultivation and utilisation

D. Zohary (Jerusalem, Israel) presented examples of the consequences of selection on the same species for different plant uses, such as seed vs. vegetative organs, or fruits vs. roots, which lead to very complex domestication syndromes. R. von Bothmer (Alnarp, Sweden) demonstrated similar effects in barley, and E. Potokina (Gatersleben) for genebank collections of *Vicia sativa*. Based on the example of African vegetable *Solanum* species, R.N. Lester (Birmingham, UK) explained the amazing diversity of forms, which have evolved among the domesticated types during only a few thousand years, by the loss of gene functions from the wild ancestors.

Other topics

In literature and paintings of the Middle Ages, allusions to the gardens of ordinary people and their plants are very rare; this is because the common, everyday things were just not worth mentioning, as A.C. Zeven (Wageningen, The Netherlands) explained on the basis of contemporary paintings. Only the plant breeders of modern times have dedicated themselves purposefully to this subject. L. Frese (Braunschweig, Germany) reported on the utilisation of the tertiary genepool in beet breeding, followed by H. Schulz (Quedlinburg, Germany) on the use of bioactive substances in foods, cosmetics and pharmaceutical products. A. Graner (Gatersleben) explained the use of molecular-genetic methods for the utilisation of plant genetic resources in breeding.

The conference was concluded by H. Bointner (Göllersdorf, Austria), the winner of the “Rudolf Mansfeld Award” for the best master’s thesis in the area of cultivated plant research, lecturing on “Breeding progress in spring barley, with special consideration of yield components”.

Of the 31 poster presentations, 28 are represented in these proceedings by at least their abstracts, in alphabetical order of their first authors. Likewise, 21 of the 23 lectures are reprinted, mostly as full papers, grouped in sections as in the programme of the symposium.

H. KNÜPFFER (Gatersleben, chairman), A. GRANER (Gatersleben), K. HAMMER (Witzenhausen), J. OCHSMANN (Gatersleben) and G. RÖBBELEN (GPZ, Göttingen) formed the scientific preparation committee. In addition, the local organising committee was complemented by N. BIERMANN, with technical support by Mrs G. SCHÜTZE (both Gatersleben).

Acknowledgements
We wish to thank numerous staff members of IPK's Department of Administration and Central Services for their assistance and smooth cooperation in financial and organisational matters. The Deutsche Forschungsgemeinschaft (DFG), the GPZ, the Society for the Advancement of Cultivated Plant Research in Gatersleben, and IPK supported the symposium financially. Their contribution to the success of the meeting is gratefully acknowledged. Several colleagues gave assistance in perfecting the English of some manuscripts. We would like to express our thanks here especially to R.N. LESTER and C. JEFFREY. Other linguistic editors are mentioned in individual chapters. Finally, we would like to thank the German Centre for Documentation and Information in Agriculture (ZADI, Bonn), especially Mrs A. SCHEIBE and Mrs G. BLÜMLEIN, for good cooperation in the preparation and production of this valuable yet inexpensive volume.

H. KNÜPFFER (Gatersleben), G. RÖBBELEN (Göttingen), J. OCHSMANN (Gatersleben)

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Invited Papers [1]

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Section 2. Taxonomy of cultivated plants

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[1] The complete programme is reproduced here. For papers without page numbers, no manuscript was submitted.

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Section 4. Diversity and evolution of cultivated plants

Section 5. Utilisation of genetic resources and plant breeding

Poster Session[2]

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[2] Only posters for which extended abstracts were submitted, are included here, in alphabetical order of their authors

Recollections of Rudolf Mansfeld[1]

P. HANELT[2]

Please allow me - as one of the few people here who actually knew Rudolf Mansfeld - to present some personal memories of him, which are vividly remembered by me as his former co-worker. When I began my service as a trainee in the then Department of Systematics and Cultivated Plant Collection (the present Genebank) of the Gatersleben Institute in 1949, Rudolf Mansfeld, the Director of this department, was ill with jaundice. In the first days of my service here, all possible opinions and prejudices against my chief were rumoured: he could be moody, mean, not artistically inclined, dreary, and a woman hater, all of which however very soon turned out to be false. From the first visit to his sick-bed I got to know him as an extraordinarily understanding man, with whom, as it soon turned out, one could co-operate very well, provided that one showed interest and commitment in the work: if this interest was missing, he could certainly be very reserved.

Rudolf Mansfeld could never hide his Berlin roots. It was his home city and for more than 20 years he was a collaborator in the world-famous Systematics School of Adolf Engler in the Botanic Garden and Museum of Berlin-Dahlem, where he had made a name for himself as an expert on various, mostly tropical, plant families, such as the Orchidaceae and Euphorbiaceae. His career as curator at this institution was interrupted suddenly when the greater part of this collection, the largest in Germany, was destroyed by several bomb raids in 1943 in the second World War. Mansfeld also suffered at that time severe personal losses: his manuscript of a monograph of the Orchidaceae for Engler's most famous work "Die Pflanzenfamilien" (The Plant Families) was burned as well as his manuscript for a revised new edition of the well-known "Flora von Deutschland" of Garcke (which was published only as the overdue revised 23rd edition in 1972!). Mansfeld never got over the loss of the Dahlem herbarium collections: he spoke of it again and again and his installation of a fire prevention system for the developing archive collections in the Gatersleben Institute was the direct consequence of this. Mansfeld was called up into the armed forces in the same year (1943) and served as an 'Obersoldat' (senior soldier) in a medical corps for the diagnosis of malaria. (He thought he might have been the only member of the armed forces to whom this obscure rank was awarded.)

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[1] Translated by R.N. Lester

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After a short time as a prisoner of war, in 1946 he acceded to a request by Hans Stubbe, the first director of the Gatersleben Institute, to work together in Gatersleben. At first he was employed as a laboratory technician with a very low salary, but before he could be established as a scientific assistant he had to undergo a de-nazification programme, in 1948. (To make the museum politically secure, the younger employees in Dahlem had been recommended by their superiors to enter branch organisations of the NSDAP - National Socialist German Workers' Party). In 1949, after the departure of W. Rothmaler to Halle, Mansfeld was appointed as director of his Department, and later, by the German Academy of Sciences, as Professor and Director at the Institute: these appointments he held until his death.

Mansfeld never had ambitions for an university career, and he therefore had not qualified as a university lecturer like many other curators; nor did he feel any urge to undertake lectures. However he loved to discuss problems of his special field with small groups or with individuals and so pass on his decades of experience in this area of systematic botany. He hated hasty conclusions and was very balanced in his arguments. Although his lectures were not brilliant as regards rhetoric (as for instance with Kurt Mothes, the director at that time of the Chemical-Physiological Department in Gatersleben), they captivated his audience by their objectivity and logical structure and in this way they resembled the lecturing style of H. Stubbe, the Director of the Institute. He spent much time in personal discussions and thus exercised on us younger ones a gentle formative influence, so that we can rightfully call ourselves his pupils. He agreed to share problems in his special field with representatives of other disciplines, which was of great importance in the Gatersleben Institute with its heterogeneous staff.

In his method of work Mansfeld needed to reorient himself again completely in Gatersleben. Previously a classical herbarium systematist, here he had to deal with collections of living plants, and systematic problems which occurred especially at the lowest levels, mostly within species, rather than at the family level. Little known is the fact that his Department was also included in the programme initiated by H. Stubbe to examine the postulates of Lysenko biology, concerning the relations between embryo and endosperm. (The conversion of one species into another, by the influence of the endosperm on the developing embryo, had been postulated with wheat-maize grafting. However the apparent development of “maize seedlings from wheat embryos” turned out to be due to production of twin embryos in the maize ovules, the second of which had not been removed).

Rudolf Mansfeld was very modest and undemanding - his life being dedicated to work, and he rarely took holidays. He never took advantage of his position and he had an outspoken aversion to privileges. An impressive example is his speedy refusal of the ‘Deputatschwein’ (payment-in-kind-pig), which in the post-war years was fattened annually for the heads of departments in the then Department of Agriculture of the Institute. After the supply situation had improved to some extent, he made no more use of this privilege. Mansfeld was among the few people I have known, who thought that their salary was unjustifiably high. He therefore put larger sums into the construction of his department and he bought the first desk lamp which I had in my work room. When in the same year a photo-laboratory was created in the Department, the equipping of this was likewise paid from his own pocket. He handled state funds exceptionally thriftily. This behaviour also shaped his colleagues at that time, and if today we still use pencil stubs down to a length of 3 cm, that is due to Mansfeld's influence! He was probably also very economical with his family budget and I can imagine that this was not always received enthusiastically by his sons, when they compared their situation with the conditions of the children of other leading colleagues of the Institute.

Mansfeld was a nomenclatural expert. He had already been given responsibility for this speciality by L. Diels, Engler's successor in Dahlem. Early in the 1930s, after almost a century of effort, the formulation of the world-wide accepted International Code of Botanical Nomenclature was drawn up, which ended the schism between American and European nomenclatural procedures. This code was published in 1935. Mansfeld was chosen for the international nomenclature commission at that time and then again after the war, in 1950. He fulfilled all requirements on this matter very conscientiously and invested very much time into answering appropriate questions and cooperation in the commissions mentioned. In connection with necessary name changes he endured much hostility, at its worst in a hearing by the Gestapo. This was because he had been denounced for correctly recognising the priority of some scientific names created by foreign colleagues from enemy states, in preference to later synonyms from German authors. He wrote in 1941, for the German Botanical Society, a nomenclature of the vascular plants of Germany (the forerunner of the standard list of Wisskirchen and Haeupler, published in 1998) and his introduction to questions of scientific nomenclature (MANSFELD 1949) I hold to be the best presentation of these problems in the German language in book form.

Mansfeld was not a traveller: before the war he visited only Vienna and the International Botanical Congress in England. Mansfeld was accustomed to a very regular life, which preferably was limited to his house and the Department. However, in the Gatersleben period he took part in an important six-month Chinese-German biological expedition to the north and north east of China, as temporary leader of the German team (when H. Stubbe was not present). The many irregularities during this collecting expedition, the frequent programme changes, the evening discussions with local authorities or institutions which often dragged on for a long time, extensive receptions with the strange Chinese cuisine (for us younger ones a source of pleasure), were for Mansfeld a torment, and he was no doubt glad in September 1956 when he could return again to his homely Gatersleben.

Mansfeld was also not a person who pushed himself forward to participate in meetings and conferences. He thought ironically then that the danger of loss of respect to his colleagues, which one might have had hitherto on the basis of publications, was always connected with personal acquaintance. (Obviously other scientists have also signified similar experiences. E.O. Wilson in his autobiography (WILSON 1994) states about J.D. Watson, the co-discoverer of the double helix structure of DNA: “I found him the most unpleasant human being I had ever met.”) More to Mansfeld’s taste were smaller meetings, workshops as we would say today, like the meeting he organised in 1957 on questions of cultivated plant taxonomy and conservation of diversity, with 10-15 participants, which, apart from two short introductions to the topic, was limited to conversations and discussions: consent in this group was easily attainable.

In Gatersleben Mansfeld occupied himself with questions of general taxonomy (his ideas on the species problem were recently taken up again here by K. Bachmann), in particular for the taxonomy of cultivated plants and for the taxonomic representation of the infraspecific diversity in species of cultivated plants. Above all the work for the classification of *Hordeum vulgare* (MANSFELD 1950) and *Triticum aestivum* (MANSFELD 1951) should be mentioned. The first edition of the cultivated plant directory (MANSFELD 1959) is referred to in other places in the present volume.

In the 1950’s the direction of systematics was dominated above all by English and American authors presenting the so-called New Systematics, which accepted features of cytology, crossability, and especially the reproduction system, as decisive criteria for the evaluation of degrees of systematic relationship and the awarding of ranks. Although Mansfeld had worked as a morphologically oriented systematist, he faced these new endeavours with an open mind, but he always warned against a one-sided way of looking at things. From the essay written from his sick-bed and published posthumously “About ‘old’ and ‘new’ systematics” (MANSFELD 1962), the following sentence is quoted: “Systematics cannot be operated under one-sided prejudice favouring the results of partial disciplines, but must take the whole of botanical research into consideration.” Even today this is extraordinarily up-to-date, when the currently dominant wave of one-sided molecularly aligned laboratories and projects threatens to wash away the diversity of the biological points of view.

Mansfeld was also often reproached for being uncultured. He provoked this surely by some of his self- ironic remarks. (I remember his description of the agonies, which he had to endure during a performance of “Fidelio” at the state opera in Berlin, squeezed into a new suit on the occasion of an Academy meeting). However he was probably joking a bit with these remarks. In China, where we were frequently invited to performances of classical Chinese operas, he was often the only one who could explain to us the actual meaning of the singular and for us strange production. Mansfeld read classical Latin literature in the original: authors such as Martial or Juvenal suited him well because of their satirical-ironical manner. He spoke fluent French and English. He always stressed the very great social responsibility of all scientists employed by society. He never excluded himself from such tough obligations, having taken part in the harvesting operations in the Department of Agriculture of the Institute, which were usual until the 1960's, or cooperating in committees such as National Education in the then Aschersleben rural district.

Mansfeld always intended to write more: he planned a presentation on the subject of general taxonomy and the history of botanical taxonomy, as well as a collection of anecdotes which would relate to taxonomy and the taxonomists in Berlin-Dahlem. It is true that only a few pages were written down and given to us (for example the anecdotes "How Graebner became professor" or "Why Engler was not awarded any Bulgarian medals").

Mansfeld had a family, a wife and two sons, whose relationships were formed by mutual respect, above all with his wife, who endured the difficult time of the bombing attacks on Berlin (and the following evacuation to Lausitz), to a large extent alone with the children. He never showed his feelings openly, but pride in his sons was always felt. The elder son, Ulrich, died unexpectedly shortly before this memorial conference; Lothar, the younger, works as a doctor in Neuss.

I would like to close with a sentence from the obituary on Mansfeld by H. Stubbe, his director (STUBBE 1962), with whom he had a very good relationship. This was based on their common fascination with plant diversity, whose study both had made their life's work, though with different goals.

"He remained faithful to the Institute for 15 years. In his quiet modesty and his incorruptible service to science he was a model for everyone, as scientist and as a human being unforgettable to us all."

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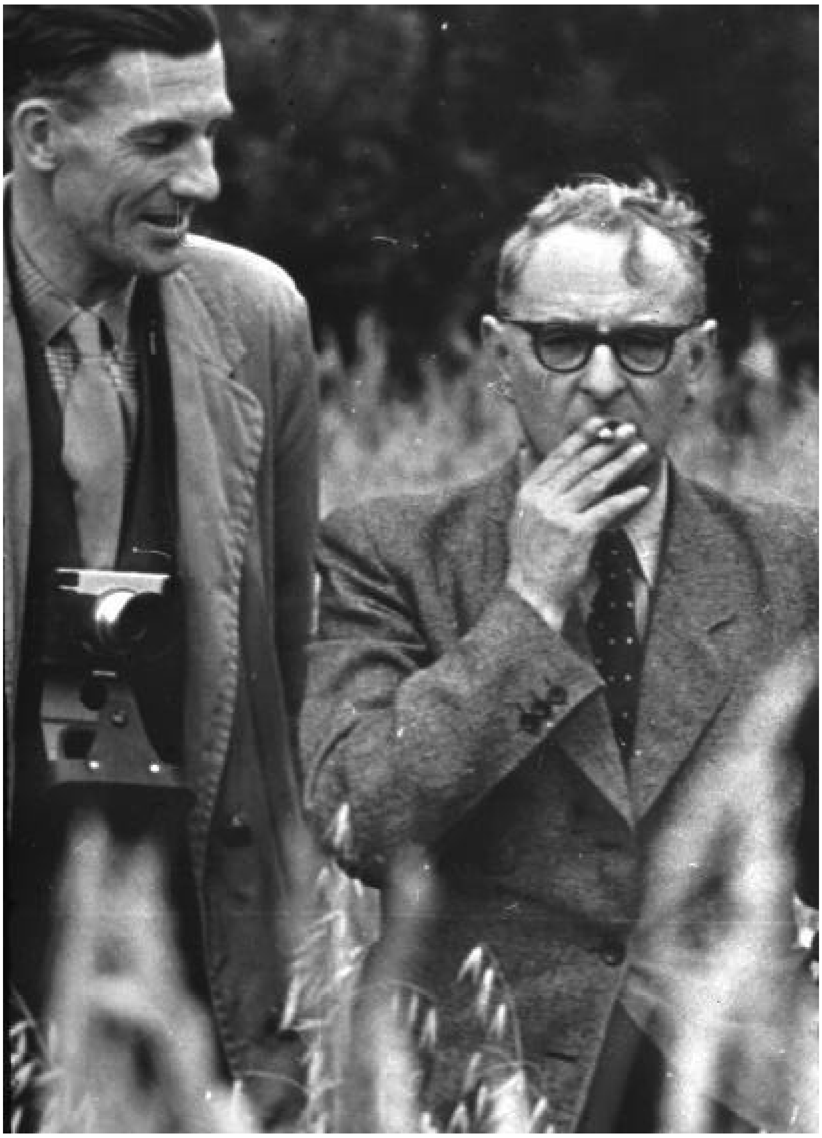

Fig. 1: Rudolf Mansfeld (on the right), together with Igor Grebenšcikov, who first applied the infraspecific rank ‘convarietas’, endorsed by Mansfeld, in his maize classification. (Photographed in 1957).

R. Mansfeld's scientific influence on genetic resources research

K. HAMMER [1]

Conclusions

R. Mansfeld actively worked within the Gatersleben Institute and tried to synthesise the different directions of research into a solid crop plant research in the sense of H. STUBBE (1957) [2]. But he was active far beyond the Institute's scope. Connections with the phytopathologists from the Halle University have been already described. There have also been working contacts with the ethnologists from the Leipzig University (see LIPS 1962) and, of course, with many colleagues from different botanical disciplines.

The integrating role of R. Mansfeld has been often appreciated (e.g., DANERT 1962, STUBBE 1962, 1982, GÄDE 1998, pp. 96-97), journals and papers have been dedicated to him (Kulturpflanze, Beih. 3, 1962, KÜHN et al. 1976, Kulturpflanze 19, 1981, PISTRICK and HAMMER 2001).

His work will stay important not only for the history of systematics and nomenclature, especially of cultivated plants, but he has also to be considered as one of the founding personalities in plant genetic resources research and genebank activities. His "Encyclopedia" lays an important foundation for further development of biodiversity research.

Summary

R. Mansfeld worked in Gatersleben for 16 years. During the last ten years he headed the Department of Systematics. At the same time, his scientific work largely influenced the new scientific field of plant genetic resources by creating infraspecific classifications for important crops, initiating evaluation programmes of barley and wheat against diseases, mounting a collecting expedition to China as the basis for many forthcoming missions, laying the basis for technical work in living plant collections, writing an encyclopaedia on crop plants and thus considering the species level for

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biodiversity research, and editing the first eight volumes of the Journal "Kulturpflanze" which is now continuing as "Genetic Resources and Crop Evolution" (vol. 48). R. Mansfeld participated in the integrated research within the Gatersleben institute and largely stimulated crop plant research as defined by H. Stubbe.

Introduction

When Rudolf Mansfeld died in 1960, the term "plant genetic resources" had not yet been created. But the work of the "Institut für Kulturpflanzenforschung" (Institute for Cultivated Plant Research) founded in 1943, was directed to basic research in crop plants (STUBBE 1957). As a taxonomist, Mansfeld not only contributed to his own field of research but he was also responsible for the living collections (later: genebank) of the Gatersleben Institute and tried to find new ways for handling and using this unique material.

In 1965, Harlan, Bennett and Frankel created the concept of "plant genetic resources". Hawkes also participated in this process (HAWKES 1997). The result was a very successful research work on crop plants including collecting, characterising, evaluating and using of landraces and wild relatives of crop plants. The highlight of this "plant genetic resources movement" (PISTORIUS 1997) reached at the beginning of the eighties of the last century, was the International Undertaking on Plant Genetic Resources. Its end was probably reached with the Convention of Biodiversity 1992 (see HAMMER 1998).

R. Mansfeld successfully contributed to the establishment of this important movement as can be demonstrated in the following. As the main source for this paper the journal "Kulturpflanze" is being used.

Infraspecific classifications

Papers on infraspecific classifications belong to the first published results of R. Mansfeld's work in Gatersleben (see DANERT 1962). Mansfeld started with the important cereals barley (1950) and wheat (1951).

Later on he continued with millets (1952) and *Physalis* (1954). His school in Gatersleben intensively continued with this work. For a mini-review see HAMMER (1981). New infraspecific classifications are still being created in Gatersleben (e.g., PISTRICK 1987 on *Raphanus*, DIEDERICHSEN 1996 on *Coriandrum*), but as relatively rare events. Internationally the interest in those classifications faded down in the last decennia, though they should be of new importance for studying this special form of diversity in the new biodiversity research (see, e.g., GLADIS and HAMMER 2001).

Evaluations

As early as in 1955, the first paper about evaluation of resistance characters of spring barleys from the Gatersleben collection against mildew appeared under the programmatic title of ”Resistenzeigenschaften im Gersten- und Weizensortiment Gatersleben” (resistance characters in the barley and wheat collection Gatersleben) (NOVER and MANSFELD 1955). R. Mansfeld was responsible for the exact characterisation and determination of the crop plant material, while Ilse Nover, a phytopathologist from the University of Halle, investigated the fungal parasite. This evaluation work was later on called “secondary evaluation” (e.g., HAMMER et al. 1998) because it is done by genebank staff in co-operation with specialists from other disciplines.

Soon the series was continued (NOVER and MANSFELD 1956, 1959; NOVER 1962), and developed into one of the most successful disease resistance evaluation programmes. The last number of the series (29) appeared in 1989 (PROESELER et al. 1989). For a brief review see HAMMER (1991) and WALTHER et al. (1997). Later on this work also included other crops than cereals with specific diseases (e.g., SCHOLZE and HAMMER 1998). The results of these studies have been of great economic importance. Between 1973 and 1990, 46 cereal varieties bred on the basis of resistance evaluations conducted in the Gatersleben genebank have been released in East Germany (see HAMMER 1991). There is a considerable delay of time between the identification of new resistance sources and their incorporation into new varieties (see table 1). This may be one of the reasons for the sporadic report about successful use of genebank material in breeding.

Tab. 1: Time span between the identification of new resistance sources and their incorporation into new cereal varieties (data from the Gatersleben Genebank, after HAMMER 1991)

Crop	Begin of testing	Literature source	Cultivar	Year of release
Spring barley	1954	NOVER and MANSFELD 1955	‘Trumpf’	1973
Winter wheat	ca. 1960	NOVER 1962	‘Compal’ ‘Fakon’	1981 1981

Travelling mission

R. Mansfeld did not like to travel (HANELT 2003. But as it was one of the tasks of the Gatersleben Institute to mount large collecting missions, he decided to participate in the Chinese-German Biological Collecting Mission through North and North-East China from May to September 1956 (ANONYMOUS 1957). During this mission, he established a special approach for investigating crop plants in their local environments, and his students transferred this knowledge to new generations of Gatersleben scientists later on (see, e.g., HAMMER 1996, p. 246 and PISTRICK 2003). Several large-style missions have been conducted by Gatersleben scientists in the fifties and sixties of the last century without R. Mansfeld but using his experiences. Crop collecting missions started again in the seventies and turned out to be very successful. Many countries were visited, and a great number of accessions was collected (HAMMER et al. 1994, App. 3 and 4). A specific Gatersleben approach has been developed and successfully followed (HAMMER et al. 1995, HAMMER 1999).

Maintaining collections

R. Mansfeld was a specialist for herbarium work (HANELT 2003). He transferred his knowledge gained from the Herbarium in Berlin-Dahlem to Gatersleben. Here, also parts from the living collection were included into the Gatersleben herbarium, forming an excellent reference collection which allows the comparison with the living material for the detection of undesired changes and consequences of mistakes in handling.

However, R. Mansfeld was also interested in the rejuvenation methods for genebank accessions. Together with Christian Lehmann he carefully analysed and described the technical details of practical genebank work in the experimental fields and wrote a first paper about this subject (LEHMANN and MANSFELD 1957). This paper was the basis for a more voluminous documentation, a typewritten book, which was circulating in the genebank under the name of "Bible" and was consulted in critical cases of genebank management. Later on, this documentation was used as a basis for a book about the Gatersleben Genebank (GÄDE 1998).

The systematic study of practical work in genebanks is still a neglected field and the publication from 1957 had very few successors, among them being the "Genebank Protocol" of the Dutch genebank (HINTUM and HAZEKAMP 1993). The publication of LEHMANN and MANSFELD (1957) deserves special interest also in another respect, as it is the beginning of reports about the activities of the Gatersleben genebank. Later on these reports were presented regularly (e.g., LEHMANN 1963) and thus helped in the compilation of the comprehensive paper on the occasion of the fiftieth anniversary of the Gatersleben genebank (HAMMER et al. 1994).

Traditionally, Botanic Gardens are publishing an Index Seminum offering their seeds for exchange with other gardens. R. Mansfeld introduced this possibility also for the Gatersleben genebank, and the first Index Seminum was published in 1947 (32 pp.). From 1953 on it appeared in the journal "Kulturpflanze" (pp. 171-227; cf. Fig. 1), proving the high quality standard of the material in the collections at that time.

Mansfeld's "Encyclopedia"

In 1959, R. Mansfeld's *opus magnum* was published (MANSFELD 1959). At that time it was by far the largest compilation of agricultural and horticultural crops (excluding ornamentals).

Whereas agri- and horticulture usually focus on the genetic (infraspecific) level of plants, Mansfeld filled a gap with respect to the specific level (Table 2). His experience in wild plants made this gap especially evident for him.

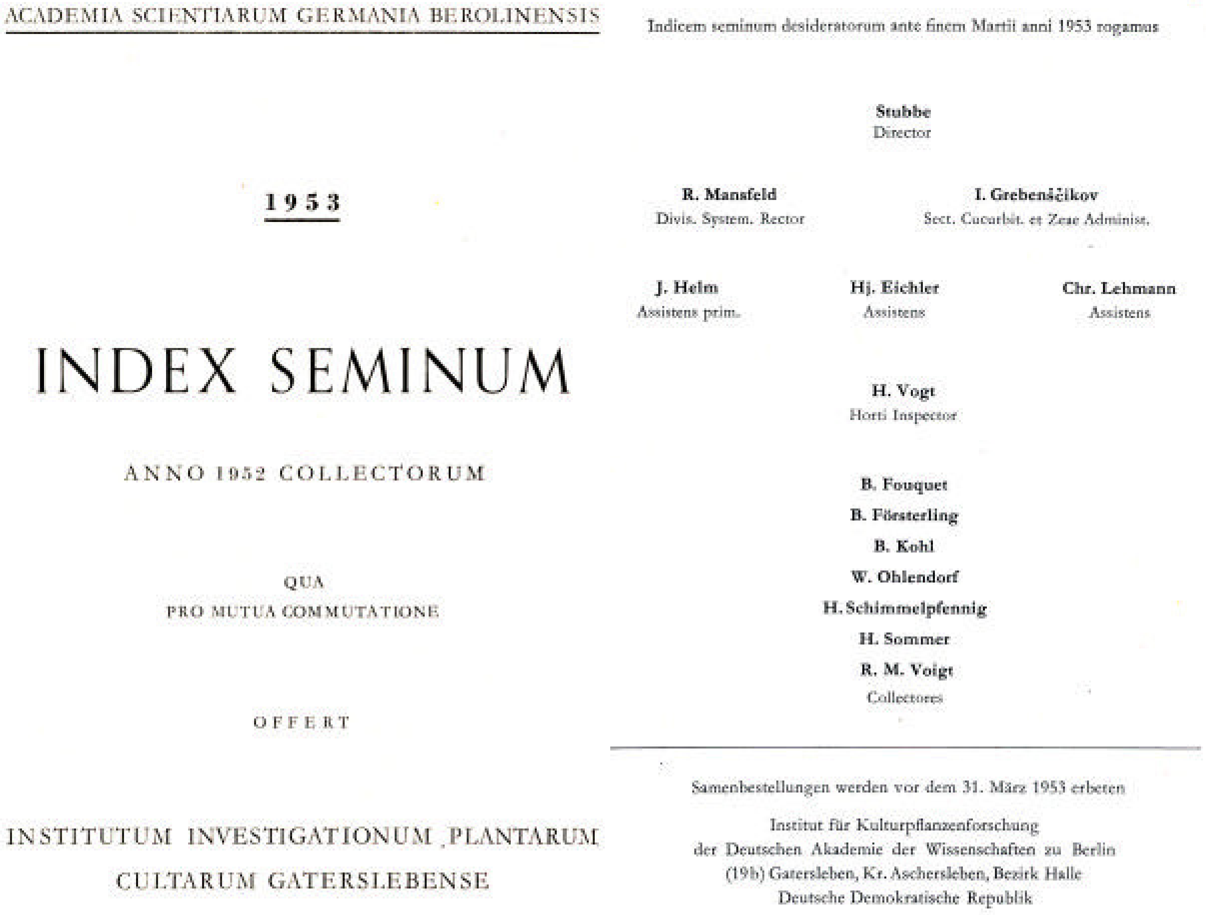
Tab. 2: Number of plant species cultivated for food and agriculture according to different inventories (after HAMMER 1995)

Source	Year	Number of species	
		Reported	Estimated total
Mansfeld, 1st ed.	1959	1,430	1,700 -1,800
Vul'f (before 1941)	publ. 1987	2,288	-
Vul'f and Maleeva	1969	2,540	-
Mansfeld 2nd ed. (J. Schultze-Motel)	1986	4,800	-
Mansfeld 3rd ed. (P. Hanelt and IPK)	2001	6,100	-
General estimate	2001	-	7,000

R. Mansfeld's work was continuously updated (SCHULTZE-MOTEL 1986), and its recent edition (HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH 2001) is the most comprehensive compilation on agri- and horticultural plants also today.

The latest edition experienced a high input of new species resulting from field work of the Gatersleben genebank in eastern Asia (HOANG et al. 1997) and Latin America (HAMMER et al. 1992-1994). New input has to be expected also from the special study of tropical home gardens in South-East Asia (see HODEL et al. 1999) and tropical Africa, where a current project is being carried out (including also Latin America) for studying, among others, species diversity (ANONYMOUS 2001).

For these ongoing studies Mansfeld's work has to be considered as an important prerequisite. The same is true for a programme stressing the importance of underutilised and neglected crops (HAMMER et al. 2001) where more than 24 monographs have already been published. All these data have been used to estimate the total number of cultivated plant species (see table 2).



ACADEMIA SCIENTIARUM GERMANIA BEROLINENSIS

1953

INDEX SEMINUM

ANNO 1952 COLLECTORUM

QUA
PRO MUTUA COMMUTATIONE

OFFERT

INSTITUTUM INVESTIGATIONUM PLANTARUM
CULTARUM GATERSLEBENSE

Indicem seminum desideratorum ante finem Martii anni 1953 rogamus

Stubbe
Director

R. Mansfeld
Divis. System. Rector

I. Grebenščikov
Sect. Cucurbit. et Zeae Administr.

J. Helm
Assistens prim.

Hj. Eichler
Assistens

Chr. Lehmann
Assistens

H. Vogt
Horti Inspector

B. Fouquet
B. Försterling
B. Kohl
W. Ohlendorf
H. Schimmelpfennig
H. Sommer
R. M. Voigt
Collectores

Samenbestellungen werden vor dem 31. März 1953 erbeten

Institut für Kulturpflanzenforschung
der Deutschen Akademie der Wissenschaften zu Berlin
(19b) Gatersleben, Kr. Aschersleben, Bezirk Halle
Deutsche Demokratische Republik

Fig. 1: Index Seminum of the Gatersleben collection, from “Kulturpflanze” 1, 1953 (front and back page)

The journal “Kulturpflanze”

From the first volume of the “Kulturpflanze” on (Berlin, 1953), R. Mansfeld was “Schriftleiter” (managing editor) until vol. 8 (1960). He helped to create an extremely useful journal publishing papers on all aspects of research done at the Gatersleben Institute. The contents shifted more and more to taxonomy and plant genetic resources research, but also included extremely important reports from the other departments of the institute. This journal survived until vol. 38 (1990) after which it was transformed into an International Journal under the name of “Genetic Resources and Crop Evolution” (vol. 39, 1992) with Kluwer Academic Publishers (Dordrecht, Hammer and Hanelt 1992). Volume 48 (1) of this journal is dedicated to the memory of R. Mansfeld on the occasion of the 100th anniversary of his birthday (Pistrick and Hammer 2001).

R. Mansfeld and the "Institut für Kulturpflanzenforschung"

Mansfeld worked in the Gatersleben Institute since 1946. Later on he became head of the department of Systematics and Collection, and member of the board of directors of the Institute. He aimed at establishing connections between the Systematics and the other departments of the Institute. Only two examples will be presented here.

With the Department of Genetics he initiated systematic studies on the artificially induced morphological variation (e.g., KRUSE 1968 in tomatoes, HAMMER et al. 1990 in snapdragons). He actively participated in the first workshop of the Biochemistry Department and co-edited the proceedings (MOTHES and MANSFELD 1956). One important later outcome of this beginning co-operation was a protein screening in the collections of cereals and pulses (e.g., LEHMANN et al. 1978).

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[see also: http://mansfeld/mansfeld/publ_mansfeld.htm].

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History of plant genetic resources and personal relationships with N.I. Vavilov and Sir Otto Frankel

J.G. HAWKES [1]

N.I. Vavilov (1887-1943)

It is one of life's curious paradoxes that, having decided to go somewhere and accomplish something, one finds that quite different ends and accomplishments are often attained. It was this sort of situation in which I found myself when I first visited the USSR in August 1938. My objective was to study the wild and cultivated potatoes collected by the Russian botanists S.M. Bukasov and S.W. Juzepczuk in Mexico and South America, as a preliminary study before I started collecting in those regions myself from 1939 onwards. However, by chance I encountered the greatest influence on my career and scientific understanding, namely Professor Nikolai Ivanovich Vavilov, the Director of the Institute of Plant Industry at Leningrad, later to be renamed in his honour.

Thus it was that in addition to studying the Russian potato collection, I was also taken by Vavilov to see his world-wide collections of wheats, barleys, oats, ryes, flaxes and other plants, and I enjoyed extensive and deep discussions with him. All was friendliness and enthusiasm, whenever I met him.

After a rather tiring first day in the field near Leningrad, studying the potato collections of Bukasov and Juzepczuk, I was taken to Vavilov's apartment, where I dined with him on that and other occasions. He was a large, jovial, hospitable and friendly person, putting me at ease and talking to me as an equal: indeed he treated all his colleagues as persons of equal attainments and understanding to himself, and thus inspired them and infected them with his enthusiasm. Even though I was only just graduated and had not yet registered for my doctoral research programme, and even though I had not yet been on my expedition in 1938-1939 to collect wild and cultivated potato species in South America, and even though I had not yet written any papers, let alone books or learned dissertations, he treated me as a fellow scholar. I could not help being impressed by his attitude towards me.

The following day, after I had been working with Vavilov's colleagues in the experimental fields near Leningrad, Vavilov "scooped me up" and took me to a dress-circle

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seat in the Opera House. As it was sung in Georgian, with a Russian verbal interpretation at the beginning of each act, I did not understand much of it! Nevertheless, the boundless energy and enormous friendliness of Vavilov, had made a great impression on me, as it did on every scientist he met.

At that time in 1938 Vavilov still received complete financial support for his Institute, due to the importance of his research and that of his colleagues. When I learned in later years of Vavilov's imprisonment and death in 1943, it affected me with great melancholy that such a person was not esteemed by the Soviet Government and was put to death on trumped up charges. On the other hand, I was proud to have met him and to have learned a great deal from his knowledge and his enthusiastic personality.

Sir Otto Frankel (1900-1998)

Sir Otto Frankel had a completely different personality from that of N.I. Vavilov. Nevertheless, they converged in their complete devotion to their work, and especially to the value of collecting and evaluating the genetic diversity of crop plants. They were also clearly devoted to the conservation and use of this diversity, in the task of breeding new and better adapted crop varieties, and the conservation of such diversity for present and future needs.

Frankel had been brought up in Vienna, but had made a name for himself as Director of Agricultural Research in New Zealand and later in Australia. He was nominated as an adviser to the Food and Agriculture Organisation of the United Nations (FAO) and he realised the threat to crop genetic diversity due to its replacement by new varieties. This was a time, over 20 years after Vavilov, when these new high-yielding and uniform varieties of crops were being introduced and cultivated at the expense of the old crop diversity in many parts of the world.

Frankel had a strong and somewhat fierce personality, but this was necessary in forcing the conservation of crop genetic diversity to be considered by research stations and governments as an extremely important aspect of plant breeding for the present and the future (see FRANKEL and BENNETT 1970; HAWKES 1978).

Frankel, together with the FAO representative, Erna Bennett, and I myself, met every year at the FAO headquarters in Rome. We discussed and argued out the ways in which this genetic diversity of ancient or traditional varieties might be conserved for the use of crop plant breeders then and into the future.

We coined the term "Genetic Resources" for this wealth of genetic diversity, to emphasise the importance of these old and very diverse crops which were being replaced by the new highly bred varieties then coming onto the market (see FRANKEL and BENNETT 1970, Genetic Resources in Plants).

Out of these discussions, grew the whole concept of Conservation of Plant Genetic Resources, initially for the diversity of ancient varieties of crop plants and their close wild relatives. Subsequently this was extended to emphasise the need for the *in situ* conservation of many more wild species and also the ecosystems incorporating them, which complemented the parallel and contemporary developments in nature conservation.

The concept of “Gene Banks” was developed for facilities to conserve, regenerate and issue plant genetic resources, whether maintained as seeds or in other living states.

Through our reports to FAO and member governments, the need grew up for the establishment of an organisation to make sure that institutions to facilitate these requirements were developed. Hence, the world organisation named “International Board for Plant Genetic Resources” was established, which later became the “The International Plant Genetic Resources Institute”, and I am very honoured to have been involved in some way with its foundation.

It is now generally acknowledged that the conservation of genetic and specific diversity, not only of plants, but also of animals, is a task that every government should support. and indeed most governments are well aware of this.

However, had it not been for Vavilov, Frankel, Bennett and others, in supporting these developments decades ago, in which I also was able to play a part, the world would be a more barren place and our agricultural systems would not be as fertile and high yielding as they now are (see also HAWKES 2001).

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Mansfeld's Encyclopedia of Agricultural and Horticultural Crops and the Mansfeld phenomenon

K. PISTRICK [1]

It is quite a difficult undertaking to discuss a book of 3,600 pages in only a few pages. Even more so, because the book is an encyclopedia and must be considered as a classical one: you have to understand the attribute "classical" not in the ironical sense of the late Rudolf Mansfeld regarding his "Die Technik der wissenschaftlichen Pflanzenbenennung" (MANSFELD 1949), as "a classic that nobody reads", but as an essential book already in several editions (Figure 1) that is being used several times a week by very many people.

"Mansfeld's Encyclopedia of Agricultural and Horticultural Crops" (HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH 2001) is a classical opus which stands alone. The "Mansfeld" is not the same as Vul'f and Maleeva's "Mirovye resursy poleznych rastenij" (VUL'F and MALEEVA, 1969), Zeven and de Wet's "Dictionary of cultivated plants and their regions of diversity" (ZEVEN and DE WET, 1982), Rehm and Espig's "Die Kulturpflanzen der Tropen und Subtropen" (REHM and ESPIG, 1996), Sánchez-Monge's "Flora Agricola" (SÁNCHEZ-MONGE, 1991), nor Wiersema and León's "World Economic Plants" (WIERSEMA and LEÓN, 1999). Nowhere can you find more concise information on accepted scientific names, synonyms, common names, natural distribution, cultivation area, uses, history of cultivation and references of all agricultural and horticultural crops (except for ornamentals) in one place.

To add at least something, please allow me some remarks on how I experienced the phenomenon "Mansfeld". I arrived at Gatersleben twenty years after the first edition of the "Verzeichnis" had been published and nineteen years after the death of Rudolf Mansfeld (Figure 2).

At that time Mansfeld's spirit was still very much alive in the Department of Taxonomy through his former assistants Dr. P. Hanelt and Dr. J. Schultze-Motel and the photographer Mrs. G. Terpe. I entered an open, pragmatic and diligent atmosphere.

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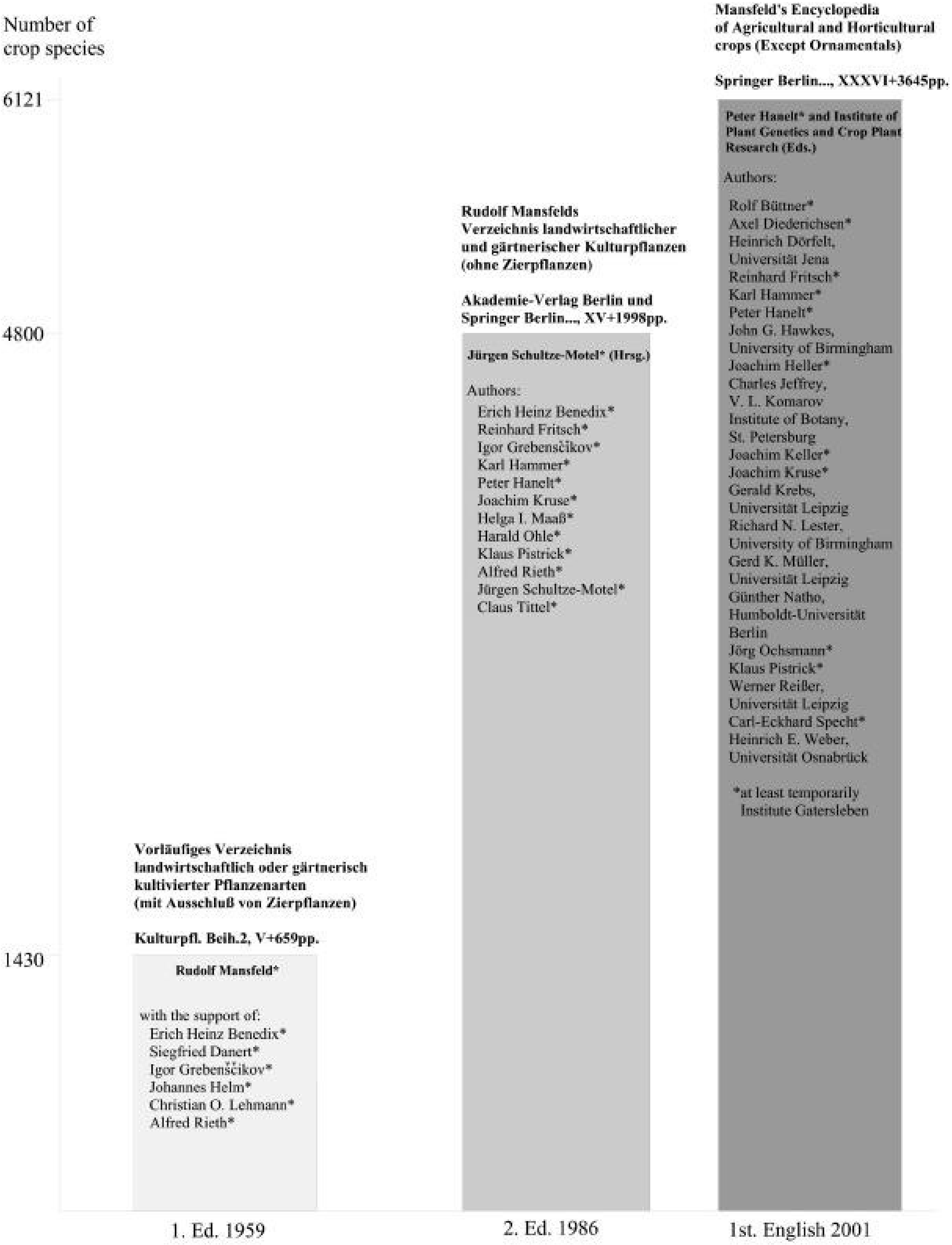

Fig. 1: **Authors of the three editions of Mansfeld's Encyclopedia and crop species numbers**

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During my first visit to Gatersleben, Dr. Hanelt made three important statements: “Yes, we need someone in the herbarium and you could work on the taxonomy of a cultivated plant.” Then he asked something about my holidays and I told him that we had found *Agrostemma githago* L. in the Slovakian Karst. ”Nice”, he said, ”we have a project there with František Kühn from Brno and you should take part in collecting missions as you already know an important indicator of landraces.” The third point was that as a new colleague I would be expected to contribute to the new second edition of the Mansfeld’s Encyclopedia. A few weeks after I had started to work at the institute, Dr. Schultze-Motel assigned many unfamiliar and as yet unassigned crop plant families such as Loranthaceae, Ochnaceae, Droseraceae or Zygophyllaceae to me for treatment. During the following years he persistently asked me about my progress in the “Mansfeld” as did Dr. Hanelt for new results of my *Raphanus*-work and for interesting observations from the field characterisation and botanical determination of the materials collected in Slovakia and Georgia.

Fig. 2: Rudolf Mansfeld (1901-1960) at the German-Chinese Biological Collecting Mission to North and Northeast China in 1956

If you receive a filing card with the six words “Pontederiaceae - *Eichhornia crassipes* - Wealth of India” it is hard work to produce the final contribution for the “Mansfeld”. During this struggle you may learn that the water hyacinth (*Eichhornia crassipes* (Mart.) Solms) is not only a pretty ornamental plant and troublesome weed in the tropics, which were for us from Eastern Germany almost inaccessible at those times, but it is also grown for fodder and as a vegetable and has an enormous potential as a fertilizer, for wastewater treatment and for the production of chemicals, fibres, biogas, etc.

The treatment of new alternative plant crops can even touch such remote questions as the conservation of whales. *Simmondsia chinensis* (Link) C.K. Schneider became very popular in arid land use in the 80s of the last century in southern U.S.A., parts of the Mediterranean, and Australia. Its valuable liquid wax is used as a substitute for sperm whale oil in the chemical industry. Today everybody knows jojoba oil, at least as an ingredient of various cosmetics and pharmaceuticals.

During the countdown to the second German edition you could often meet three or four authors at the same time in the small room of the Department's reference library. All of them were busy looking for essential information regarding the taxa they were working on, but discussed briefly new findings or nomenclatural difficulties. One of them, Claus Tittel, demonstrated how to work according to Prof. Mansfeld's parsimony principle using very small pencils with prolongation and brown packing paper for writing his notes. I myself struggled to find my way when answering the following main questions: What literature is available at Gatersleben, what information may I find and accept from which source, and where I can find reference texts such as the "ING Book" (Index Nominum Genericorum), "Wealth of India", "Kul'turnaja Flora", "Englers Pflanzenreich", "Economic Botany" or "Flora Malesiana"?

The growth of the stock of references related to plant genetic resources (PGR) available in the Scientific Library at Gatersleben is shown in Figure 3. The library has been a principle source of information for all editions of Mansfeld's Encyclopedia. Despite many new sources of online information, the need to have hard copies of a wide range of relevant literature in Gatersleben, both for germplasm-taxonomy and for encyclopedic work, is today as urgent and essential as it has always been. For substantial support of the library during the last ten years we are grateful to the Deutsche Forschungsgemeinschaft.

Striking the balance of all editions of our encyclopaedia (Figure 1) we have to understand that many of the authors worked in the tradition of Rudolf Mansfeld. They identified personally with this book, and sometimes it became a matter close to their hearts: Dr. Hanelt spent five years of his retirement as an author and editor of the 3rd edition (= 1st English ed.).

At a Mansfeld-party with IPK's director Prof. U. Wobus in 2001 we encountered Dr. R. Büttner from the Fruit Genebank at Dresden-Pillnitz, but only in the afternoon: "No", he said, "I came already in the morning, using this opportunity to visit the library. I'm already preparing for the 4th edition!"

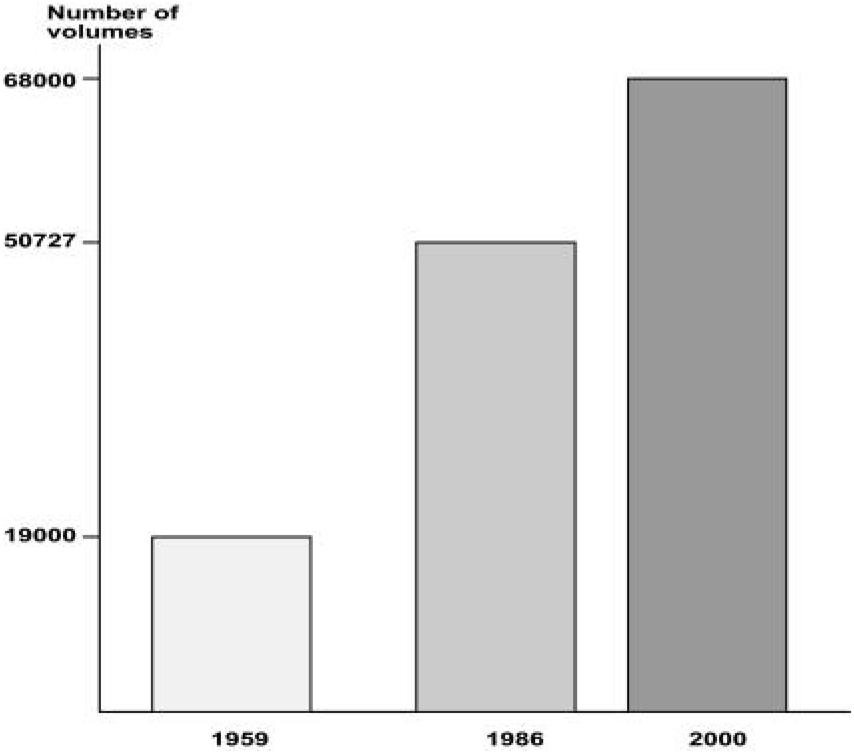

Fig. 3: The holdings of the Gatersleben Scientific Library at the time of publication of all editions of the Mansfeld's Encyclopedia

The increasing number of known crop species reflects the intensification of taxonomic and ethnobotanical research as well as the various selection and breeding activities to improve and to broaden the spectrum of cultivated plants. Since the time of Rudolf Mansfeld, the Gatersleben institute has made several significant contributions in this field, as presented by Prof. K. Hammer in this volume. During his numerous collecting missions he developed a very successful "Mansfeld view" for new crop plants (HAMMER 1991), and after every expedition in which I took part he asked. "Could you find a new Mansfeld species on your trip?" However, this is quite difficult, especially outside the tropics. Nevertheless here are some examples:

Lavandula multifida L., cultivated for scent and transplanted as a medicinal plant from the wild into house-gardens in South Tunisia (PISTRICK et al. 1994).

Crataegus dzhairensis Vass., an endemic fruit tree cultivated in orchards of the Hissar Mountains in Uzbekistan.

Ribes janczewskii Pojark., a shrub species, transplanted into gardens for its edible fruits, in the same region (PISTRICK and MAL'CEV 1998).

Some other taxa, which had been thought to be extinct in parts of their former areas of distribution, were rediscovered, e.g., *Cucumis melo* var. *flexuosus* (L.) Naud., the snake melon, in South Tunisia (PISTRICK et al. 1994).

Amaranthus lividus L. convar. *lividus*, an old vegetable with purple coloured broadened stems, had been reported as "now probably only in Botanical Gardens" in the second Mansfeld edition: we found it in Central Romania in traditional cultivation (PISTRICK 1996).

Of all the 240,000 higher plant species presently described, 2.5 % are cultivated as agricultural and horticultural crops (except ornamentals). The top ten families with the largest numbers of species are clearly led by the Leguminosae and Gramineae (Table 1).

Tab. 1: The "Top ten families" of Mansfeld's Encyclopedia

Family	Species number	Percentage of crop plants	1st German ed. 1959	2nd German ed. 1986	1st English ed. 2001
Leguminosae	18,000	4.2	196	658	759
Gramineae	9,500	7.1	183	596	670
Compositae	22,750	1.2	47	215	271
Rosaceae	2,825	9.1	82	226	258
Euphorbiaceae	8,100	2.2	28	136	181
Labiatae	6,700	2.6	38	129	174
Palmae	2,650	5.8	23	82	154
Solanaceae	2,950	4.5	48	115	132
Umbelliferae	3,540	3.2	30	78	113
Rutaceae	1,800	5.1	30	78	92

In all these families the numbers of species treated increased very greatly from 1st to 2nd editions, with yet more additions for the 3rd edition. Let us have a closer look on the Umbelliferae and Labiatae, for which I was more or less responsible during this last revision. Major uses could be indicated for all species by commodity groups following the Mansfeld data (PISTRICK 2002). Numerous neglected and under-utilised crops of interest for future breeding activities are included in these overviews, as well as many little known possibilities of their utilisation.

Solid information for the 3rd Mansfeld edition has been provided by recent taxonomic revisions of germplasm collections at Gatersleben, such as those of *Brassica* L. by GLADIS and HAMMER (1992) or *Coriandrum* L. by DIEDERICHSEN (1996). During her recent analysis of morphological and chemical characters of the genus *Ocimum* L., Sabine Eckelmann found a rather isolated position for *O. basilicum* ssp. *minimum* (L.) Danert in Mansf. This taxon had been combined as a subspecies of *Ocimum basilicum* L. by Danert in the 1st edition and its position needs further investigation by comparison with all closely related taxa, such as the botanical varieties of *Ocimum basilicum* L. ssp. *basilicum* and *Ocimum americanum* L. ssp. *americanum*.

The paragraph on the genus *Ocimum* in the "Vorläufiges Verzeichnis" (Mansfeld's draft catalogue) is a good example of the more detailed presentations down to the infraspecific level generally provided in the first edition of Mansfeld's Encyclopedia. This can be explained by a closer look at the conception of the original encyclopedia. Following his "Verzeichnis der Farn- und Blütenpflanzen des Deutschen Reiches" (MANSFELD 1940), Mansfeld prepared a list of cultivated plants as early as 1943, but the manuscript was destroyed during the war. In Gatersleben, he initially intended to write a comprehensive flora of cultivated plants with descriptions of all important infraspecific taxa. This plan was changed pragmatically, taking into account the large number of species and the limited Gatersleben staff resources. That this was a wise decision is obvious from the recent edition of Mansfeld's Encyclopedia, which is still considered as a short version in spite of consisting of six volumes, or from the amount of information on the now eight *Ocimum* species.

Nevertheless, practical solutions in infraspecific plant taxonomy have been a major goal for research in Mansfeld's tradition (HAMMER 1981). In the genus *Raphanus* for instance, one taxon produces long edible fruits: this commodity group has been classified as *Raphanus sativus* L. convar. *caudatus* (L. fil.) Pistrick. Those taxa used as vegetables for their thickened roots and tubers have been named convar. *sativus* (PISTRICK 1987). Further infraspecific classification based on different colour characters may be difficult within genebank management, particularly for allogamous taxa, such as a radish accession from Maramures (Romania), displaying the whole spectrum of secondary rind coloration of taproots and tubers. For infraspecific grouping, the taxonomic category "convarietas" (convar.) has proved to be suitable in species of cultivated plants. It has been used for a long time by the Gatersleben school, e.g. by Igor GREBENŠCIKOV (1949) in *Zea mays* L. or by Rudolf MANSFELD (1950) in *Hordeum vulgare* L., and cannot be replaced by the category "cultivar-group" proposed by the "Cultivated Plant Code" (TREHANE et al. 1995) for "assemblages of two or more similar, named cultivars", because the convariety is also applicable for land-races or primitive forms, which cannot be classified into cultivar-groups.

Nomenclatural codes are a help in stabilization of scientific names, but there remain some difficult problems to be resolved. For example MABBERLEY et al. (2001) recently proved that *Malus pumila* Mill. should be used as the correct name of the cultivated apple instead of the familiar *Malus domestica* Borkh. Moreover, they even say that the genera *Pyrus* L. (the pear) and *Malus* Mill. (the apple) will be recombined ultimately under the older name *Pyrus* following molecular phylogenetic data. – For our reference book we should carefully consider such developments but we should never forget our responsibility for practical naming. The motto should be: As much stability in botanical nomenclature as possible. Changes should be made only when these are strictly necessary. An example in this direction was given by R.N. Lester and J.G. Hawkes in the recent Mansfeld edition. They did not unify *Solanum* L. and *Lycopersicon* Mill., so potato and tomato will keep different scientific genus names as well as vernacular names. – *Solanum uporo* Dunal in DC. is an example of a plant used and cultivated only historically, because the fruit was commonly consumed by cannibals in association with human flesh.

Other species, such as *Allium victorialis* L., have only recently been taken into cultivation, because they are being over-collected from their wild habitat (BERIDZE et al., 1987). In Figure 4, the editor of the 3rd Mansfeld edition is shown while fishing successfully in the pickles after one week of hunting fruitlessly for this taxon in the Central Caucasus for the Gatersleben *Allium* project. In future, new crops for new uses will be found even among hitherto undescribed plants from the tropics. An example is the tropical liana *Ancistrocladus korupensis*, described by THOMAS and GEREAU (1993) from Cameroon, which contains michellamine B, an alkaloid with antiviral activity against HIV.

Mansfeld's Encyclopedia seems fairly complete and the targeted user community should find all the data they expect to find in this book. This was even investigated experimentally: when presenting his "Vorläufiges Verzeichnis", Rudolf Mansfeld asked the ethnologist Eva Lips for three species names. She named *Bixa orellana*, *Ananas sagenaria*, and *Acer saccharum*. All had been included. – Prof. K. Bachmann continued this public experiment in a seminar forty years later: he asked a Thai colleague from the auditorium for a vernacular name of an uncommon crop. She mentioned "kamin", and this name for *Curcuma longa* L. had in fact been recorded by the author, Dr. J. Kruse.

In the future we have to realise a warning formulated by SMALL and CATLING (1999) in their "Canadian Medicinal Crops": "The quality of information on the internet varies from excellent to erroneous and highly misleading." That means that the responsibility of authors in selecting relevant information for their respective crop groups will be even higher for a future edition of Mansfeld's Encyclopedia. Nowadays we have much more information but increasingly less knowledge. "We have not only genetic erosion in plant genetic resources, but also competence erosion" said Prof.

G. Röbbelen during a GPZ (Gesellschaft für Pflanzenzüchtung) meeting. The "Mansfeld" will be a weapon against this competence erosion in plant genetic resources.

Fig. 4: Peter Hanelt eating pickled *Allium victorialis* L. on a collecting mission in Chevsuretia (Great Caucasus) in 1986

Looking at the scientific credo of Rudolf Mansfeld (Figure 5), we understand three points: High responsibility for our field of science; rational global thinking; and a high ethical standard. In order to continue these traditions for Mansfeld's Encyclopedia as the opus magnum of Rudolf Mansfeld and the IPK Gatersleben we need in my opinion only two things:

Three additional enthusiastic taxonomists at Gatersleben, who are urgently needed for keeping up with the botanical determination work in the genebank collection as well, but also further support by external collaborators throughout the world.

Acknowledgements

I wish to thank Dr. P. Hanelt, Dr. J. Schultze-Motel and Mrs. G. Terpe for interesting discussions concerning the Rudolf Mansfeld era at Gatersleben, Dr. S. Eckelmann for unpublished results of her work on *Ocimum,* M. Altstadt for library statistics, Dr. A.

Diederichsen, Mrs. S. Houben, Dr. J. Kruse, and Prof. Dr. R. Rieger for critically reading the manuscript and U. Tiemann and K. Lipfert for graphical work.

„Die botanische Systematik hat die große Vielfalt der Pflanzen der Erde zu erfassen, beschreibend darzustellen und übersichtlich zu ordnen. Das ist eine praktische Notwendigkeit; die Menschheit muß sich in der Vielfalt orientieren und darüber verständigen können. Erst damit wird eine rationelle Nutzung der Pflanzen möglich, ebenso wie die wissenschaftliche Erforschung der Pflanzenwelt, die die Grundlagen für die mit der Zunahme der Bevölkerung der Erde nötige ständige Verbesserung dieser Nutzung liefern muß."

"Systematic botany has to document, present descriptively and classify in an organised manner the tremendous global plant diversity. This is a practical necessity: Mankind needs orientation and means for efficient communication about diversity. Only if based on this, are rational use and scientific investigation of plants possible, and these have to establish the foundation for continuous improvement of plant use which is necessary for the increasing human population on earth."

Fig. 5: The scientific credo of Rudolf Mansfeld (MANSFELD 1962)

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The “Mansfeld Database” in its national and international context

H. KNÜPFFER [1], J. OCHSMANN [2] and N. BIERMANN [1]

The “Mansfeld Database” (Mansfeld’s World Database of Agricultural and Horticultural Crops) is an online database that reflects the contents of “Mansfeld’s Encyclopedia of Agricultural and Horticultural Crops” (HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH 2001). For further details, see OCHSMANN et al. (2003), KNÜPFFER et al. (2002), or http://mansfeld.ipk-gatersleben.de/mansfeld/.

The institutional context

To avoid redundancies in the data the “Mansfeld Database” consists of several modules containing different data types, such as taxonomic data and names, full text information, plant uses, images, or references. This structure enables easy adding or linking of further data types, such as evaluation or geographical data.

The “Mansfeld Database” with its more general information on a worldwide scale complements other local databases such as the IPK Genebank Accessions Database or the Database for Checklists of Cultivated Plants (KNÜPFFER and HAMMER 1999).

The national context

The “Mansfeld Database” is part of IPK’s contribution to the project “Federal Information System on Genetic Resources” (BIG, http://www.big-flora.de/), which involves four partner institutions, coordinated by the German Centre for Documentation and Information in Agriculture (ZADI). The project is funded by the German Federal Ministry of Education and Research (BMBF) for five years (1998-2003) and includes, besides the “Mansfeld Database”, also information on plant genetic resources (PGR) accessions of genebanks in Germany, botanical gardens, floristic mapping of the

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German flora, and other PGR-related data sets (ROSCHER et al. 2003). Through a common search interface at ZADI, it is possible to interrogate these heterogeneous databases simultaneously, for example, by scientific or common names of plants.

The "Mansfeld Database" will also be made available in the framework GBIF-D (http://www.gbif.de) project via an individual search interface. This project, also funded by the BMBF, will build up the German contribution to the Global Biodiversity Information Facility (GBIF; http://www.gbif.org).

The international context

Linking with other databases

The "Mansfeld Database" provides the opportunity to create automatic links to and from external databases using standard HTML requests. In this way, the "Mansfeld Database" is connected with the GRIN Taxonomic Database of Agricultural Plants (http://www.ars-grin.gov/). Additionally, automatic links from the "Mansfeld Database" to the following databases have been established:

- ITIS (Canadian version) - Integrated Taxonomic Information System,
- Plants for the Future Species Database [test only],
- NCBI Database for Nucleotide Sequence Data,
- NCBI Database for Protein Sequence Data,
- NCBI Database for Molecular Structure Data,
- NCBI PubMed Database for References.

Integration in international projects

Cultivated plants have been generally excluded from European flora database projects (e.g., Flora Europaea, MedChecklist) in the past. The "Mansfeld Database" offers an opportunity of standardising the scientific nomenclature and taxonomy for cultivated plants. In the framework of the EU project "European Network of Biodiversity Information" (ENBI, http://www.faunaeur.org/enbi/ info.html) approved mid 2002, it would therefore complement the European "wild plant databases" very well. Since many plants cultivated in the European and Mediterranean region have been derived from the wild flora, a considerable overlap between these groups of species can be expected. It is also desirable to complement the general information in the "Mansfeld Database" by country-specific studies, especially for European countries. For Italy, such inventories of cultivated plant species have already been published (HAMMER et al. 1992, 1999). Initiatives in this direction have started, e.g., on an EU scale (i.e., IPK's role in ENBI) and within ECP/GR. It was also proposed to use the "Mansfeld

Database" as a taxonomic backbone to the central database EURISCO of plant genetic resources in European collections to be created within the EU project EPGRIS by end of 2003.

The "Mansfeld Database" is permanently being completed by images, especially of genebank accessions and herbarium specimens, and by common names of plants in different languages.

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A Species Compendium for Plant Genetic Resources Conservation

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Introduction and background

Decisions on conservation methods for *ex situ* conservation of plant genetic resources depend strongly on biological parameters of the species to be conserved. Knowing whether a species is seed or vegetatively propagated; producing orthodox or recalcitrant seed; if it is annual or perennial, an inbreeding or outbreeding species; which are the seed germination requirements etc., is crucial for devising suitable conservation methods.

These parameters are largely species specific and do not vary over time, thus they seem to be data that can be easily managed in a database. However, no focused database or publications existed in the beginning of the 1990s that would have provided an information source on seed physiology characteristics related to conservation. Consequently, the International Plant Genetic Resources Institute IPGRI started, through a collaborative project with the University of Reading and Kew Royal Botanic Gardens, the compilation of a compendium on seed storage behaviour. This compendium was meant to serve as a guide for genebank managers/curators and other conservation scientists in the maintenance of their collections, and provide information to seed collectors devising appropriate methods of handling and storing seeds over the short-term.

It is IPGRI's mandate to advance the conservation and use of plant genetic resources for the benefit of present and future generations. Among the institute's strategic choices there are the improvement of conservation strategies and technologies and the increased use of plant genetic resources (IPGRI 1999).

Developing seed storage techniques has been a major research focus of the International Board for Plant Genetic Resources (IBPGR), IPGRI's predecessor. Further improving these techniques, developing new ones and making them more widely applicable and available remained an important element of IPGRI's research agenda.

Already in the 1980s a set of benchmark handbooks on seed technologies for genebanks had been produced (Fig. 1), in conjunction with the University of Reading and

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other collaborators. The seed storage behaviour compendium was published in 1996 (HONG et al. 1996) as fourth handbook in IPGRI's series of Handbooks for Genebanks.

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IPGRI Technical Bulletin No. 1: HONG, T.D. and R.H. ELLIS. 1996. A protocol to determine Seed Storage Behaviour. IPGRI, Rome, Italy.

Fig. 1: A series of benchmark handbooks

In addition to the seed storage behaviour compendium, a protocol to determine seed storage behaviour was developed (HONG and ELLIS 1996). It provides an approach by which conservationists and genebank managers can determine whether or not long-term seed storage is feasible for a particular species, i.e. whether or not that species shows orthodox seed storage behaviour. It is intended to be used along with the Compendium, as these two products are essentially complementary. The overall aim of the protocol is to guide and encourage further work in this area of seed physiology (particularly for species on which relatively less work has been done to date) with the objective to expanding on/up-dating the type of species-specific data compiled in the compendium.

The protocol to determine seed storage behaviour was published as IPGRI's first Technical Bulletin (HONG and ELLIS 1996). In the same year, work started on a second set of data on dormancy and germination requirements of seeds and later on pollen storability (IPGRI 1996).

The Seed Storage Behaviour Compendium

Following its initial release as a hard-copy publication, the Compendium has been developed into a searchable electronic database - the Electronic Seed Storage Be-

The **Compendium** provides an introduction to seed storage physiology and a selective summary of the literature on seed storage behaviour for:

- **7155 species**, covering approximately **1000 genera**, belonging to **251 families**
- Species are classified into one of eight seed storage behaviour categories
- Over **1000 bibliographic references** are included: For most species, this systematic classification is further supported by a brief summary of the storage conditions which have been applied and/or studied as well as key references to the literature
- **Other pertinent species-specific data are also provided** where available, including: common names and synonyms; distribution and ecology, and 1000-seed weight

The eight categories of seed storage behaviour in the Compendium: summary of classification criteria and % breakdown of the total number of species classified under each:

- **"Orthodox": 62%**
  The category "Orthodox" is used where it could be determined with certainty that the species shows orthodox seed storage behaviour.
- **"Orthodox?": 18%**
  This classification implies that the probability that the species shows orthodox seed storage behaviour is greater than about 50% but that further investigation is likely to be necessary before attempting storage at the IPGRI preferred conditions for long-term seed storage.
- **"Orthodoxp": 9%**
  (Orthodox probable) This classification suggests a high probability that the species shows orthodox seed storage behaviour. This category has been used where seed viability has been successfully maintained for (3 years but <10 years in open storage at "ambient" temperatures.
- **"Intermediate": 1%**
  Species classified in this category have seeds that tolerate desiccation to about 10-12% mc, but further desiccation reduces viability, and/or there is more rapid reduction in viability during the storage of dry seeds at cooler than at warmer temperatures.
- **"Intermediate?": 1%**
  This category includes species where "excessive" drying has been reported to damage seed viability and/or in cases where seed physiological characteristics (e.g. seed size, ecology) are analogous to closely-related species with known "intermediate" seed storage behaviour.
- **"Recalcitrant": 3%**
  This category includes all species for which the lowest "safe" moisture content exceeds 20% mc and where no evidence to the contrary has been found.
- **"Recalcitrant?": 4%**
  Species provisionally classified as "Recalcitrant?" include all those which are generally "short-lived", whose viability is difficult to maintain and/or for which only "moist storage" recommendations are available in the literature.
- **"Uncertain": 2%**
  Finally, this category has been applied for species where the data preclude classification into one of the above groups.

Fig. 2: Seed Storage Behaviour Compendium

haviour (ESSB) Compendium, first in a DOS environment and then also as a Windows version. The DOS based version was released in 1997. In August 1997 already more than 100 copies had been distributed and requests continued to arrive on a weekly basis. The Windows version is available, since January 1999, for download from IPGRI's web site at http://www.ipgri.cgiar.org/system/page.asp?theme=1. During the months July 2000 to February 2001, the database was downloaded 49 times from IPGRI's web site, this equals about 7 downloads per month. Both DOS and Windows versions of the database are also available on floppy disk from IPGRI. The aim is to ensure that this publication is available to all those who need it and to make it easier for users to retrieve species-specific information on seed storage behaviour.

The Compendium is also available as hardcopy from Kew Gardens who published it with IPGRI's agreement in 1998 (HONG et al. 1998). The information is an integral part of Kew's Seed Information Database. The first module of that database is now available online at http://www.rbgkew.org.uk/data/sid/ and contains all of the storage behaviour data in a searchable format.

The Compendium consists of two sections. Part I summarises progress made over the past two decades in the understanding seed physiology in relation to seed storage and longevity for genetic resources conservation. Part II of the publication, i.e. the part that has been configured as searchable database, is a summary of the literature on seed storage behaviour for over 7.000 species from 251 families. Species are listed alphabetically by family and genus and are systematically classified into one of eight categories of seed storage behaviour (see Fig. 2). For each species, a brief summary of the storage conditions that have been reported and/or studied is given, including citations of key references to the literature. The references cited in the Compendium form an extensive bibliographic database that includes more than 1.200 entries. In addition, basic information on the geographic distribution and the thousand-seed-weight (TSW) are summarised for each species. Where available, vernacular names and botanical synonyms are also listed.

The ESSB can be searched by family, genus, species, common name, storage behaviour, references and notes from a simple search screen as well as from a complex search screen (Fig. 3). Drop down menus are available for all searchable fields except the notes and reference fields. For these fields, a wildcard operator is used which means that the user is required to enter the criteria as a "string" or word pattern that the software will then search for. This operation is available also for the common name field, in addition to the drop down menu. All drop down lists are alphabetised. The note field allows the user to add personal notes and information to the database. The information contained in the Compendium is of "dynamic" nature. New findings complement existing information and/or disprove the findings of previous studies. There are a number of species for which seed storage behaviour classification is controversial and others for which seed storage characteristics have yet to be deter-

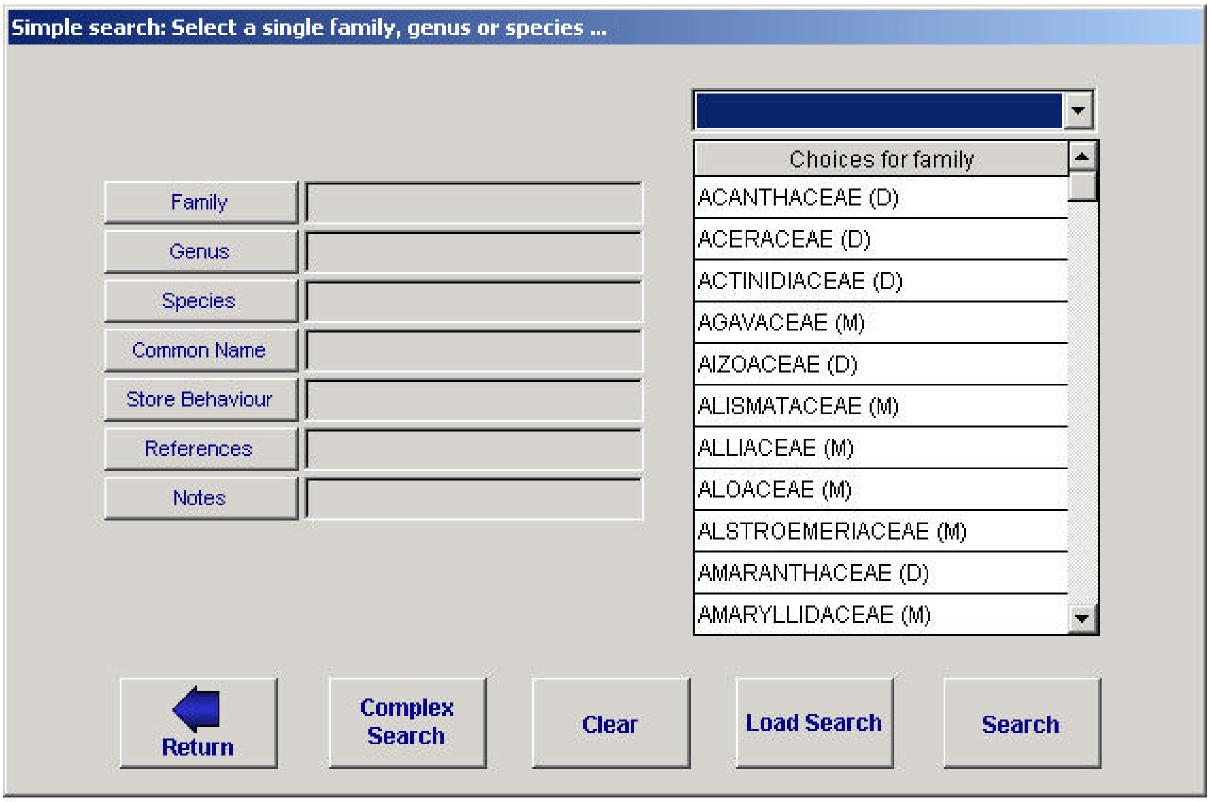

Fig. 3: Search screen of the ESSB

mined. Both the scientific community (seed physiologists and seed conservation researchers) as well as genebank managers/curators are important contributors of new information.

Extension of the Compendium: Species Compendium for PGR Conservation

Since its completion IPGRI has envisaged the Compendium as a framework for the development of a much broader information resource, encompassing major topics in each of the principal disciplinary areas of *ex situ* conservation of plant genetic resources. The plans to extend the Seed Storage Behaviour Compendium into a "Species Compendium for Plant Genetic Resources Conservation" consider the following areas for the extension:

- Seed germination requirements and dormancy
- Pollen storability
- Diseases affecting storage of germplasm, with a strong focus on viruses and indexing and therapy protocols

- Amenability of species for *in vitro* storage and/or cryopreservation, including existing *in vitro* and cryopreservation protocols and references
- Reproductive systems and pollination ecology, including parameters such as in- or outbreeding, annual or perennial, pollinators (e.g. insects – which ones –, wind, etc.) isolation requirements for multiplication, etc.
- Additional miscellaneous parameters such as centre(s) of origin/diversity, geographical distribution, taxonomic nomenclature (including correct spelling of preferred names and synonyms), etc.

The information about seed germination requirements and dormancy has already been collated into a “Compendium of Information on the Dormancy and Germination of Seeds of Selected Trees and Shrubs”. About 1.500, predominantly woody species are included, and for each species listed information (if available) is presented in up to eight sections. These sections are common names, distribution and ecology, plant characteristics, evidence of dormancy, germination regimes for non-dormant seeds, successful dormancy-breaking treatments, nursery practice and further information.

Approximately 3.000 literature references have been collected about pollen storability and specific information on pollen storage behaviour of about 1.600 species is available.

The extension procedures will start with the improvement of the database structure of the ESSB and the conversion of the data into a standard desktop database (i.e. MS-Access). The data about germination and dormancy will be configured in an Access database with an analogous structure to allow merging it with the ESSB. Other species-based datasets might be added in cooperation with other information suppliers or potential partners. To avoid duplication of efforts, to develop the right structure for the Species Compendium and collocate it within the already existing projects on genetic resources information, the European and global scene needs to be assessed.

A web-enabled search interface will be developed and hosted by IPGRI, probably mirrored elsewhere, to allow searching the databases through the web. Creating a web-enabled updating mechanism, including the implementation of an author-curator model is also taken into consideration. All extension procedures, standards applied (taxonomy, quality, etc.) as well as the history will be thoroughly documented.

Due attention will be given to data ownership, copyright issues, custodianship and acknowledgement of contributors, curators and editors.

It has already been pointed out that the information contained in the Compendium is not of “static” nature. Thus, it needs to be discussed how best to motivate scientists to contribute and to use the Compendium. One aspect is certainly to provide easy access to all users around the world by means of different media, such as the internet, off-line download, CD-ROM and hard copies. Easy access should be linked to an easy and direct way to provide any feedback including notification of mistakes spotted by the user and new data to be contributed to the database. Another aspect to consider in this regard is also how far access and use of the entire dataset for integration with other datasets and/or commercial use such as Mansfeld's Encyclopedia (HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH 2001) might be permitted.

Conclusion

Based on the experiences made with the Compendium so far, it can be concluded that a real need exists to access the type of information as provided in the Compendium. It is envisaged that a user-friendly information source on the internet will certainly further increase the use and dissemination of this type of information for conservationists, and that a database which can be updated by the scientific community and is clearly kept in the public domain, will provide for an existing need in the PGR community.

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Some notes on problems of taxonomy and nomenclature of cultivated plants

J. OCHSMANN [1]

Abstract

The last two editions of the International Code of Nomenclature for Cultivated Plants (ICNCP) have seen a distinct reduction of the number of accepted categories due to the adoption of the culton concept. In contrast to the International Code of Botanical Nomenclature (ICBN),which is still a system exclusively for scientific use, it is the scope of the present ICNCP to provide a simple system for practical purposes and for a very diverse group of users with different intentions. Many problems related to synonymy result from the vast number of categories that have been introduced in the past. The comparison of different taxonomic works is further complicated by the sometimes very limited use of categories or their re-definition. Additional problems arise from incompatibilities between the Codes on different levels. The classification under the ICBN at present normally implies a phylogenetic background, but the ICNCP is aiming at providing a formal classification for practical use. The culton concept as a non-hierarchical system is incompatible with the hierarchical system of the ICBN, which results in problems with name conversions. Apart from these general problems, the acceptance of the ICNCP is very low as 1) for certain taxonomic aspects there is a lack of accepted categories, 2) the rules for naming cultivars are still too complicated or restrictive for practical use, and 3) the important commercial sector with trade-marks is not covered by the ICNCP. For the future, a harmonisation and consequent use of the Codes is necessary. Additionally, rules for naming clades have to be included because of the increasing amount and importance of molecular data. A great advance in this process will be the development and establishment of world-wide databases providing tools for linking and maintaining information on the relationships of plant names.

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Introduction

The first written record on the naming of cultivars was published about 160 B.C. by Cato, yet it took more than 2,000 years before the first Code on the Nomenclature of Cultivated Plants (ICNCP) was published as a separate document in 1953. A detailed review of the history was given by the famous W.T. STEARN (1986).

The principles of the nomenclatural system have been quite stable in the past: "wild" and cultivated taxa were classified mainly on the basis of morphological characters and grouped in a hierarchical way. The classification was a formal one and the categories used were compatible. The situation remained the same when the first ICNCP was published (STEARN 1953), but in "wild plant taxonomy" the idea of phylogenetic reconstruction instead of formal classification became more and more important. A whole host of problems came up with the use of the term "variety" as a formal category under the International Code of Botanical Nomenclature (ICBN) and simultaneously for cultivars. Various attempts to solve this problem have been made by proposing a vast number of new categories for cultivated plants.

In its last two editions (BRICKELL et al. 1980, TREHANE et al. 1995) the ICNCP has undergone dramatic changes, resulting in a reduction of the number of accepted categories and the adoption of the culton concept of HETTERSCHEID (1994) and HETTERSCHEID and BRANDENBURG (1995). This system is a non-hierarchical, open classification that is mostly incompatible with the classical system: for cultivated plants there are only two ranks (cultivar and cultivar-group) that can be placed anywhere under a genus, a species, a subspecies, a varietas or a forma. Furthermore, the same cultivar is allowed to belong to different cultivar-groups at the same time. Whereas the ICBN is still a system entirely for scientific use, the scope of the present ICNCP is to provide a simple system for practical purposes for a very diverse group of users with different intentions. As the culton concept is not very popular it is the intention to eliminate it from the next edition of the ICNCP (TREHANE 2001).

Present situation

Because of incompatibilities between the two Codes on different levels, the present situation is rather complex:

- Whereas the classification under the ICBN (GREUTER et al. 2000) today normally implies a more or less phylogenetic background, the aim of the ICNCP (TREHANE et al. 1995) is to provide a formal classification for practical use.
- The culton concept as a non-hierarchical system is incompatible with the hierarchical system of the ICBN.

- Under the present Codes there are no rules for the treatment of clades, which become more and more important with the widespread use of molecular markers

The present system is far from being satisfactory, but many problems with synonymy result from the vast number of categories and definitions from the past. The sometimes very limited use of categories or the re-definition of existing ones makes the comparison of different treatments very difficult, if not impossible. In the context of preparing "Mansfeld's Encyclopedia of Agricultural and Horticultural Crops" (HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH 2001) and the development of an online-database (OCHSMANN et al. 2003) a number of questions and problems concerning taxonomic categories and their complex relationships came up. For that reason an online-database with various information on the different taxonomic categories and their relations was developed (http://mansfeld.ipk-gatersleben.de/taxcat2/). An example is given in Figure 1. The information was taken from several sources. The complex nature of the "synonymy" of the taxonomic categories is obvious; besides chains of synonyms there are net-like structures, too.

Apart from these general problems the acceptance of the ICNCP seems to be extremely low because of several reasons:

1. Taxonomists working on cultivated plants constitute a minority of all practising taxonomists.
2. For certain scientific aspects there is a lack of categories accepted by the ICNCP, causing problems in the conversion of names (see example below) and a lack of information (re-use of names, no necessity of authorities).
3. The rules for naming cultivars are still too complicated or restrictive for non-taxonomists.
4. For purposes of stability there are too many exceptions from the rules.
5. The big commercial sector with trade-marks is not covered by the ICNCP.

Example from the Mansfeld Database

The term "convarietas" was introduced by GREBENŠCIKOV (1949) for groups of varieties of cultivated plants that do not fulfil the criteria of subspecies. According to JIRÁSEK (1958) the terms "convar" and "convarietas" are equivalent. The "convarietas" was adopted as an accepted category by the ICBN in 1952 (LANJOUW et al. 1952), but was no longer included after the introduction of the ICNCP in 1953. In the ICNCP the term "convarietas" is only treated in the 1958 and 1961 editions (Art. 14) as a supplementary category, but is not mentioned in the 1969 edition (GILMOUR et al. 1969). Generally, the use of additional ranks is permitted by the ICBN (Article 4,

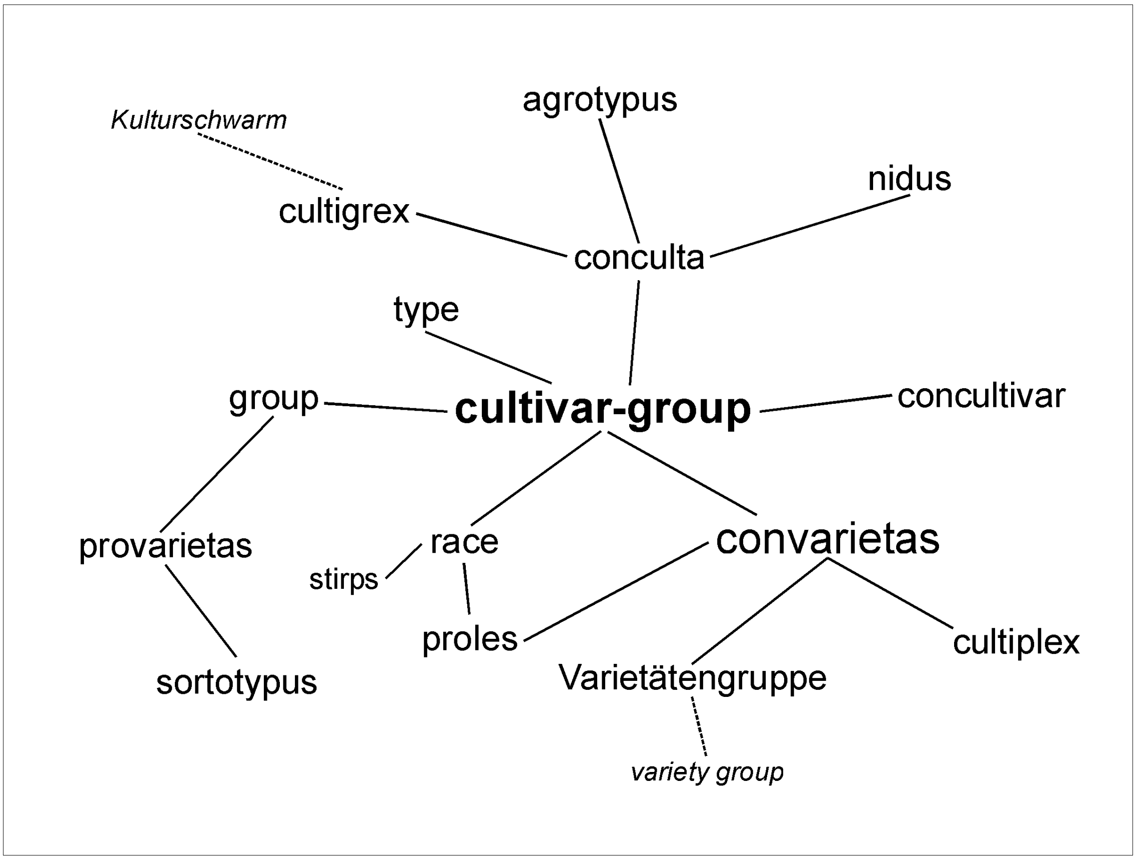

Fig. 1: Relations between a number of taxonomic categories according to different sources (bold: accepted category according to the ICNCP; dotted lines and *Italics*: vernacular names)

GREUTER et al. 2000: "Further ranks may also be intercalated or added, **provided that confusion or error is not thereby introduced**." [emphasis added]), but "convarietas" is explicitly mentioned in Article 4, Note 2 of the recent ICNCP (TREHANE et al. 1995): "Prior to the introduction of cultivar-groups in this *Code*, authors may have used other designations such as **'convar'**, 'sort', 'type' or 'hybrids' as terminology equivalent to cultivar-group; **such terms are to be replaced by 'cultivar-group'**" [emphasis added].

Though not being an accepted rank any more, the "convarietas" today still is in wide use, so that its future treatment by the Codes should be discussed further (see JEFFREY 2003).

The subspecific classification of *Brassica oleracea* ssp. *oleracea* used in HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH (2001) is based on the category "convar.". Two new combinations on the rank of "convar." have been made in *Brassica oleracea* ssp. *oleracea*, though they seem to be in conflict with the Codes (see above). The reason for the enduring use of "convar." was that converting this system to a classification based on cultivar-groups would have affected 18 taxa and resulted in a loss of taxa. The two possibilities of adapting the names to the rules of the ICNCP are shown in Figure 2.

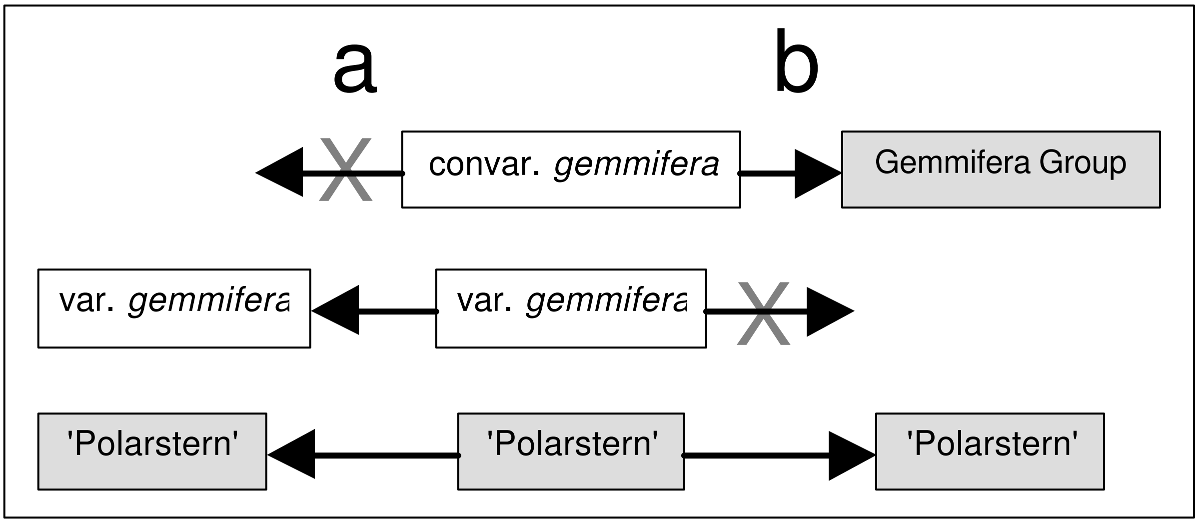

Fig. 2: *Brassica oleracea* ssp. *oleracea*: Two possibilities of adapting the nomenclature to the rules of the ICNCP (grey boxes: ranks governed by the ICNCP)

In the first case (Fig. 2 a) the convarieties ("convar.") are eliminated and the varieties are maintained. In the second case (Fig. 2 b) "convar." is converted to "cultivar-group" according to Art. 4 of the ICNCP. This would result in the elimination of all varieties ("var.") because only cultivars are allowed below the rank of cultivar-group. It becomes obvious that important information on the taxonomic structure of the group is lost in both cases due to the elimination of categories. This loss of information is regarded as one of the major disadvantages of the culton concept even if it works well in practice in certain plant groups (e.g. *Beta*, see FRESE 2003).

Another source of trouble are some existing gaps in the definitions of the ICBN and the ICNCP (Principle 2, ICNCP, TREHANE et al. 1995): "The *International code of botanical nomenclature* (*ICBN* or Botanical Code) governs the botanical names in Latin form for both cultivated and wild plants, except for graft-chimeras which are entirely governed by this *Code*. **Distinguishable groups** of cultivated plants, whose origin or selection **is primarily due to the intentional actions of mankind**, are to be given epithets formed according to the Rules and provisions of the *Code*." [emphasis added]. Depending on the subjective decision of the author a new taxon, only known from cultivation, may be described as species, subspecies, varietas or forma under the ICBN or as cultivar under the ICNCP. If a cultivated plant had been given a cultivar name, but later is found in the wild, too, the wild plant has to be newly described under the ICBN. The same is true for many weedy forms of cultivated plants that escaped from fields or gardens and established themselves in the wild (crop-weed-complexes). On the other hand it remains questionable if laciniate or variegated forms taken into culture from the wild differ from the wild populations in the sense of Principle 2 of the ICNCP so that they can be given a cultivar name.

How can taxonomic relationships between cultivated plants and their wild relatives be expressed when two different naming systems can be used in the same plant group?

At present the ICBN also has to face dramatic changes: With the rapid developments in molecular techniques large amounts of new data are available that cannot be easily handled with a closed hierarchical naming system without a big number of nomenclatural changes (e.g. clades).

For that reason a system of "phylogenetic nomenclature" (DE QUEIROZ and GAUTHIER 1992 and 1994), that claims to provide the solution for the future, is promoted (see PhyloCode, CANTINO and DE QUEIROZ 2000). Examples using the classical system and the phylogenetic approach alternatively were presented by CANTINO et al. (1998 and 1999). The discussion regarding the PhyloCode (see ongoing discussion in Taxon and other journals, e.g., BRUMMITT 1997, CANTINO 1998 and 2000, DE QUEIROZ 1997, LEE 1999 and 2001) seems to suffer from misunderstandings, mainly caused by a lack of communication between "classical taxonomists" and "phylogenetic nomenclaturists". The PhyloCode is a non-hierarchical, phylogeny-based system of rules for the naming of clades that avoids nomenclatural changes only due to the maintenance of the hierarchical structure of the names. The major disadvantages are 1) the mixing of nomenclature and taxonomy, 2) the general assumption of tree-like phylogenies (causing problems in the case of hybridisation and introgression), 3) the assumption of species as basic units, 4) the necessity of world-wide registration of names (just eliminated from the recent ICBN), and 5) the lack of reference to the ICNCP and cultivated plants.

It seems highly questionable, whether the PhyloCode will lead to a stable and objective classification, because the consequences of the application of some rules remain unclear. Instead, taxonomists who know the problems and pitfalls of synonymy, priority, and name changes already solved or avoided in the past, should work out modifications of the present ("Linnean") nomenclatural system.

Some prospects for the future

Though stability of names is one of the first principles of both the ICBN and ICNCP, one has to distinguish between changes due to new results in taxonomic research and changes due to nomenclatural reasons (e.g., name conversion or shift of ranks).

While the first type of changes will always be necessary, the second type of changes should be avoided as far as possible. In this respect, it is highly necessary to provide special rules and non-hierarchical categories for units like clades or populations of wild or cultivated plants. Additionally, the importance of nomenclature and taxonomy must be explained to non-taxonomists by better co-operation between the ICBN and ICNCP and a consequent use of the Codes by all taxonomists, avoiding ambiguous terms like “variety” for cultivars in literature.

Helpful in this respect will be the development and establishment of world-wide taxonomic databases providing tools for linking and keeping information on the relations of different names.

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Theoretical and practical problems in the classification and nomenclature of cultivated plants, with examples from Cucurbitaceae and Compositae

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Abstract

Some provisions of the Botanical and Cultivated Codes concerning the taxonomy and nomenclature of groups of cultivated plants are discussed with respect to problems of taxonomic structure, ranking, homonymy, typification, publication, priority and user-friendliness. It is concluded that the application of both Codes variously, as a given situation demands, will best provide the flexibility advantageous in the naming of groups of cultivated plants.

Introduction

The names of plants in cultivation are regulated primarily by two codes of nomenclature: the ICBN (GREUTER et al. 2000) and the ICNCP (TREHANE et al. 1995). The relationship between the two is not complementary. Art. 28 of the Botanical Code while recognising the regulation by the Cultivated Code of particular, additional designations of groups of cultivated plants nevertheless states, that there are no obstacles to the use of names regulated by the Botanical Code for such groups. On the other hand, the Cultivated Code recommends the use of names regulated by the Cultivated Code for taxonomic groups of cultivated plants that meet the criteria of being recognised as cultivars or cultivar-groups. There is thus an overlap or even an antagonism, the implications of which, be they advantageous or disadvantageous, require discussion.

Taxonomic structure

The system of names governed by the Botanical Code was developed during the 18th, 19th and 20th centuries to serve a taxonomy, the aim of which has been, and is, to discover the natural system, or, in contemporary terms, to construct hypotheses of

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the hierarchy of life, and thus maximise the information content of the system (SCHUH 2000).

The hierarchical relationships of character-states and taxa was perceived even before a scientific theory to account for it – Darwinian organic evolution – was put forward, and long before a method, other than purely intuitive analysis, for constructing such hypotheses – Hennigian cladistics – was discovered. The success of the intuitive method is a result of the fact that our cognitive mechanisms are evolutionarily adapted to deal with the hierarchical patterns of our world (RIEDL 1984).

From the above, it is clear that the following question must be posed. Do those taxonomic groups of cultivated plants to which the nomenclatures of both the Botanical and the Cultivated Codes may be applied likewise exhibit hierarchical structure, i.e., hierarchical patterns of relationships between character-states and between taxa? The answer must be no, at least in part. This is acknowledged by the Cultivated Code in its provision that a cultivar may be simultaneously assigned to more than one cultivar-group, and cultivars as defined by the Cultivated Code can by no means all be considered as products of processes analogous to Darwinian evolution, i.e., processes giving rise to a hierarchical relationship of character-states and taxa. Consequently, hypotheses of hierarchical structure may not always give the most informative classifications of cultivated plants. In other words, to paraphrase Ludwig Wittgenstein, what is or is not a particular cultivar is for the public to decide.

Thus it may be concluded that, other things being equal, a system of categories and names independent of those of the Botanical Code, such as those provided for by the Cultivated Code, is to be preferred, at least for some groups of plants in cultivation. A corollary of this may be, that a general term for taxonomic groups of cultivated plants, other than “taxon”, such as, for example, “culton”, should also be preferred.

Practical considerations

This discussion leads us to pose, of course, the question: But are other things equal? Here we pass from consideration of the theoretical to consideration of the practical. In the practical employment of any regulated system of nomenclature for taxonomic groups of plants, the following are some considerations of importance: ease and reliability of determining the status of names; ease and reliability of determining the application of names; and the user-friendliness of the system. These points will now be discussed.

Determination of the status of a name involves ascertainment of whether or not it is in accordance with those articles of the relevant Code governing valid publication (Botanical Code) or establishment (Cultivated Code) and legitimacy (accordance with the rules of the Code) such as to allow it to compete with other names for the purposes of priority (Botanical Code) or precedence (Cultivated Code). Determination of the application of a name involves establishment of the material basis to which it is permanently linked (typification under the Botanical Code, establishment of the standard, if any, under the Cultivated Code) and of the taxon within the range of variation of which that material basis is considered to fall. Names applicable to the same taxon that are of appropriate status compete for the position of the correct (accepted) name for that taxon, according to the principle of priority (Botanical Code), or precedence (Cultivated Code) as construed by the Code concerned. This involves ascertainment of their dates of valid publication or establishment. User-friendliness involves, among other things, consideration of the value of vernacular versus Latin epithets, and of the systems of ranks of taxa employed.

It is not possible here to give the detailed comparison of the Botanical and Cultivated Codes that would be required conclusively to answer the question posed above – are other things equal? But it will be useful to consider a number of cases in which especial problems are involved in the application of one or other of the two Codes.

Ranks and their order

The Cultivated Code recognises the equivalence of vernacular terms such as the English “variety”, and the term “cultivar”, and the equivalence of vernacular terms such as “convar” or “hybrids” and the term “cultivar-group”. It also states that the botanical category “varietas” is not the equivalent of cultivar and must not be so treated. However, it does permit a Latin epithet of the name of a taxon of the rank of species and below to be retained as a cultivar epithet when that taxon is changed in rank to that of cultivar, except in the case of autonyms. Likewise, a cultivar-group epithet may be in Latin form if based on an accepted cultivar epithet or other epithet in Latin form used in the denomination class. The Botanical Code provides for a strict hierarchy of ranks, the relative order of which must not be changed, and permits the addition and intercalation of additional ranks when considered necessary. From this, it follows that an epithet published in Latin form for the name of a taxon at the rank of convarietas can be used in a botanical name only for a taxon between the ranks of subspecies and varietas, whereas, used as a part of a cultivar-group name, it can be used in combination with a generic, specific, subgeneric or varietal Latin (Botanical Code governed) name of a taxon. Here the greater flexibility provided for by the Cultivated Code may be considered advantageous (see Fig. 1). On the other hand, there is nothing in the Botanical Code to prevent the recognition of a taxon of wild plants at the rank of convarietas.

- *Cucurbita pepo*
  - ssp. *pepo*
    - var. *fraterna*
    - var. *pepo*
      - Aurantia Group
      - Pumpkin Group
      - Styrian Hulless Group
      - Vegetable Marrow Group
      - Vegetable Spaghetti Group
      - Cocozelle Group
      - Zucchini Group
  - ssp. *texana*
    - var. *texana*
    - var. *ovifera*
      - Ornamental Gourd Group
      - Scallop Group
      - Crookneck Group
      - Straightneck Group
      - Delicata Group
      - Acorn Group

Fig. 1: The classification of *Cucurbita pepo*
Note that the cultivar-groups are subordinated to varietates. If these groups were recognised as convarietates, then it would be necessary to raise the varietal taxa to a rank (e.g., infraspecies) intermediate between subspecies and convarietas, as the rank of varietas is subordinate to the rank of convarietas.

Denomination classes and homonymy

Under the Botanical Code, the use of the same epithet in heterotypic names of two or more taxa of infrageneric, supraspecific rank, or of infraspecific rank, irrespective of the actual ranks of the taxa concerned, is not permitted. Only the earliest of such homonyms may be taken into consideration for purposes of priority in establishing the correct name of a taxon; the others must be rejected as illegitimate. However, the use of the same infraspecific epithet for names of taxa subordinate to species placed under different species or genera is allowed. This provision is advantageous in the naming of cultivated plants, as it permits the use of the same epithet in the names of corresponding elements of two or more homologous series of infraspecific taxa of two or more different species within the same genus, as well as for those in different genera. On the other hand, under the Cultivated Code, the taxon within which the use of a cultivar or cultivar-group epithet may not be duplicated is the denomination class, which is a genus unless a special denomination class (which may be wider or narrower than a genus) has been determined by the International Commission for the Nomenclature of Cultivated Plants. In Compositae, for example, *Cichorium* and *Lactuca* fall within one denomination class, as in Cucurbitaceae do all the species of *Cu-*

curbita and *Citrullus* and the species *Cucumis melo*. Consequently, for example, the use of the convenient cultivar-group names *Lactuca sativa* Cutting Group and *Cichorium endivia* Cutting Group for groups of cultivars of similar use practice in these two species, is not permitted, and one of these names must be replaced (see Fig. 2). The same applies to the names *Cucurbita maxima* Austroamerican Group, and *Cucurbita moschata* Austroamerican Group, for groups of primitive cultivars or landraces of these two species with similar geographical provenance (see Fig. 3). Nonetheless, I have considered it useful to adopt these names for the groups concerned in the new "Mansfeld" (HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH 2001).

Cichorium endivia
- ssp. *pumilum*
- ssp. *endivia*
    - Cutting Group
    - Batavian Group
    - Curled-leaved Group

Lactuca sativa

Supergroup 1	Supergroup 2
Sativa Group	Latin Group
Stalk Group	Butterhead Group
Cos Group	Crisphead Group
Oilseed Group	
Cutting Group	

Pterocypsela indica (L.) Shih 1988 (*Lactuca indica* L.)
- Dracoglossa Group
- Laciniata Group
- Indivisa Group

Fig. 2: The classification of *Cichorium endivia*, *Lactuca sativa* and *Pterocypsela indica*

A. Note that the use of the two "Cutting Group" names is contrary to the provisions of Article 6.1 of the ICNCP, as both species fall within the same denomination class (ICNCP, Appendix IV).

B. The species *Lactuca sativa* L. was transferred by SHIH in 1988 to his newly-established genus *Pterocypsela* Shih. Does this constitute division of a denomination class under Article 6.3 of the ICNCP? See also Article 6.3, Note 2.

- *Cucurbita maxima*
  - ssp. *andreana*
  - ssp. *maxima*
    - Parvifructina Group
    - Austroamerican Group
    - Zapallito Group
    - Banana Group
    - Hubbard Group
    - Mammoth Group
    - Turban Group

- *Cucurbita moschata*
  - Austroamerican Group
  - Mexican Group
  - Palaeotropical Group
  - Eurasian Group
  - Cheese Group
  - Japonica Group

Fig. 3: The classification of *Cucurbita maxima* and *Cucurbita moschata* Note that the use of the two "Austroamerican Group" names is contrary to the provisions of Article 6.1 of the ICNCP, as both species fall within the same denomination class (ICNCP, Appendix IX).

Under the Botanical Code, it is quite clear that homonymy is permanent – "once a homonym, always a homonym" – and cannot be affected by any subsequent nomenclatural act. But under the Cultivated Code, it appears that this is not always so. What happens when a cultivated species, belonging to a given denomination class, is transferred to another genus that is not included in that denomination class? In other words, is the transfer of a cultivated species from one genus which is a part or the whole of a denomination class, to another genus outside that denomination class, to be construed as division of a denomination class, as provided for by Art. 6.3 of the Cultivated Code? It is not clear from Art. 6.3 whether or not this is so, without an announcement and publication by the appropriate statutory or international plant registration authority (see Fig. 2). But if the answer to this question is "yes", then an epithet previously rejected as duplicated in the former, broader denomination class, may have to be reinstated for a cultivar within the new, narrower denomination class under the provisions of Art. 10.1 of the Cultivated Code.

Typification

The application of names governed by the Botanical Code is determined by means of nomenclatural types. In the Cultivated Code, there is no mandatory provision for typification, although the analogous process of establishing standards is recommended. As a consequence, the application of names under the Cultivated Code might be considered less certain and less easy to determine than under the Botanical Code. From this follows the great importance accorded to the registration of names by the Cultivated Code, in contrast to the Botanical Code, into which attempts to introduce registration have justifiably been rejected by the taxonomic community. On the other hand, this lesser certainty is offset by the fact that the typification of many botanical names, published for taxa of cultivated plants below the rank of genus before 1 January 1958, is often extremely difficult. Since the majority of such names were published by botanists working in institutes in eastern Europe and northern Asia, there is a very great need for the compilation of a catalogue and data-base of type specimens of names of taxa of cultivated plants conserved in the herbaria of the countries concerned. Such a project might well be undertaken jointly by the Vavilov Institute in St. Petersburg and IPK Gatersleben, and funding might be sought from organisations interested in promoting scientific cooperation between western Europe and Russia.

Valid publication and priority

Determining the usability and correctness of names involves, among other things, ascertaining whether or not they meet the criteria of valid publication (Botanical Code) or establishment (Cultivated Code), and of the date of publication of the work, if any, in which these criteria were met. Both for names of cultivated plants governed by the Botanical Code, and for those governed by the Cultivated Code, there are particular difficulties in this process. From 1 January 1953, exact citation of place of publication of the basionym, and exact indication of rank, and from 1 January 1958, indication of the type are criteria which must have been met for botanical names to have been validly published. These provisions have often been overlooked by those publishing botanical names. On the other hand, such demands are not made by the Cultivated Code for the establishment of the epithets of names of taxa of cultivated plants, which may even be established simply by inclusion as an accepted denomination in a register maintained by a statutory plant registration authority. These less formal processes, however, may be considered more easily to lead to nomenclatural duplication and uncertainty as to the correct name of a cultivated taxon. Also, a name effectively but not validly published before 1 January 1959 under the Botanical Code might have to be regarded as providing an established cultivar or cultivar-group epithet if the provisions of Arts. 2.2 and 22.1 of the Cultivated Code are met.

User-friendliness

The use of epithets in the vernacular, and the establishment of names by descriptions in any language, may be considered by many to be more user-friendly than the mandatory use of Botanical Latin for the names and validating descriptions under the Botanical Code. However, freedom from the demands of Latin may make it easier for unqualified or incompetent persons to make contributions to the nomenclature of cultivated plants, which might not always be advantageous. The simpler (two-tiered) system of ranks of the Cultivated Code might likewise be considered more user-friendly than the system of the Botanical Code, where there are at least three ranks, and any number of supplementary ranks may be used, below the rank of genus. On the other hand, for complex crops of world-wide distribution, which may have involved two or more independent domestications, the simpler system may sometimes be considered inadequate. In the long run, the question of user-friendliness may depend upon how easily and how reliably the questions that form appendices 7 and 8 of the Cultivated Code can be answered.

Conclusions

The above discussion has shown that there are disadvantages and advantages in the nomenclatural systems of both the Botanical and Cultivated Codes; that is, other things probably are equal. Botanical Code names should preferably be used for taxa of cultivated plants down to the level to which the hierarchical structure of the variation is conserved; it may be that of a group of two or more hybridising genera or species, a genus, a species, a subgenus, a convarietas or a varietas. For the discussion, use and marketing of plants of taxa that meet the criteria of being a cultivar, Cultivated Code names should preferably be used. An assemblage of cultivated plants, including (but not exclusively) an assemblage of two or more cultivars, which shows one or more characters that make recognition of the assemblage as a named group to be desirable, should preferably be given a cultivar-group name. The category convarietas should preferably not be considered the equivalent of cultivar-group, but should be included as an additional botanical rank between subspecies and varietas, more adequately to express the hierarchical pattern of variation at that level. This implies, of course, the possibility of the acceptance of taxa of wild plants at the convarietal rank; the possibility of a cultivar-group and a convarietas being coextensive is of course not excluded. The cultivar-group name will be subject to the homonymy requirements of the denomination class, but the name of the convarietas will not.

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Development of Vavilov’s concept of the intraspecific classification of cultivated plants: case studies in genera of the Fabaceae family

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Introduction

Until recently, the term systematics has been used synonymously with the term taxonomy, even by biologists. However, the doctrine of classification of organisms is only one of several purposes of systematics. Plant classification begins from their inventory, or cataloguing, by identification, and ends with the assignment of the plants to certain taxa. Another element of systematics is nomenclature, i.e., choosing or establishing the correct scientific plant name in accordance with the nomenclatural system. The next and the most important purpose of systematics is the construction of a modern phylogenetic, genealogical system, to reflect the affinity between taxa of different ranks and the evolution of the plant world.

Ultimately, the main task of a taxonomist is to find the single right place in the evolutionary system for the taxa he/she deals with. To achieve this aim, an the taxonomist needs expertise knowledge of many different branches of biology.

When analysing the development of plant systematics from the period of construction of artificial to natural and, finally, to modern phylogenetic systems, two stages can be distinguished within the last period: the stage of “population systematics, based on the interpretation of the species as a complex of local populations”, and the stage of “creation of synthetic systems”, i.e., the making-up of systems by a synthesis or combination of different approaches (MELIKYAN 1984).

The crucial problem of not only plant systematics, but also biology in general, is the concept of the basic taxonomic category, i.e., the species, especially its circumscription and structure. According to VAVILOV, “the history of systematics of cultivated plants is illuminative. It shows how a scientist had to change his view of the species step by step”. The concept of the species changes, “depending on the level of development of the biological science, the purposes of systematisation and the methodology of a researcher” (KONAREV 1995). There were differences in the circumscription of species, which led to an extensive discussion, and even a struggle in the 1930-50s (ROZANOVA 1946) between the proponents of “macro-” and “microspecies”, that is,

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the proponents of polytypic (“the species is a system”, VAVILOV 1931) and monotypic (“the species is a geographic race”, KOMAROV 1940) species concepts.

Summarising this debate, TAKHTAJAN (1965) noted: “Now we are facing the necessity of elaborating the intraspecific systematics of the most important plants of the flora of the USSR.” Recent scientists mostly agree that “species can be defined as a complex genetic system, however, with a common gene pool, protected from penetration by genes from other species by biological isolation barriers” (YAKOVLEV and AVERYANOV 1997). Nevertheless, this discussion has not yet been finished, and proponents of both points of view can be found among Russian botanists.

When trying to trace the sources of this discussion, TAKHTAJAN (1965) noticed that works on biosystematics, i.e., “differential systematists” in VAVILOV’s (1965) terms, “dealt mainly with cultivated plants but also partly with their relatives”, while systematists working on wild plants supported “small species”. The latter can partly be explained not only by theoretical considerations (species as a geographic race), but also by the feasibility of an inventory of a vast number of species in the USSR area when writing the multi-volume work “Flora of the USSR” (1934-1957).

In fact, in the 1930-40s, VAVILOV and his co-workers assembled a vast amount of plant material in the Institute of Plant Industry, namely, a living collection and a parallel herbarium collection of cultivated plants and their wild relatives. The living collection was subjected to complex detailed investigations both by the method of “geographical sowings” in a network of experimental stations established all over the former Soviet Union (cf. for example for barley, KNÜPFFER et al. 2003), and by many different biological methods (cytological, genetical, physiological, anatomical, etc.). “The investigation of cultivated plants for the purposes of breeding, as well as for better comprehension of problems of their evolution, requires the application of differential systematics. Breeders and agronomists have to distinguish not only species but also varieties” (VAVILOV 1965).

On the one hand, VAVILOV interpreted the term differential systematics as a consideration of the species as a complex of “geographical and ecological types” and subordinate intraspecific taxa (VAVILOV 1931, 1965), which consists of “a discrete system of hereditary forms”. On the other hand, he then writes: “We are now entering the era of differential, ecological, physiological and genetical classification”, and interprets “differential systematics” as the application of a complex of methods for the analysis of intraspecific systems. TAKHTAJAN (1965) calls the “differential systematics” also “biosystematics” and “experimental systematics”, which “summarises and synthesises” results of other botanical and biological sciences.

History of systematics of cultivated plants

The history of systematics of cultivated plants goes back to pre-Linnaean times. In particular, CLUSIUS's collection of tulips is well known, where special emphasis was given to characters important for gardeners and customers (CLUSIUS 1601, TJON SIE FAT 1992).

CAESALPINO, the "Aristotle of the 16th century", was the first to suggest to base plant classification on characters inherent in a plant, instead of those important for man (KOMARNITSKY et al. 1975).

LINNAEUS regarded some domesticated plants as conspecific with wild species, but with a different intraspecific rank analogous to "subspecies", whereas he regarded other domesticated plants as distinct species and then subdivided these into intraspecific groups. Thus, the description of the domesticated species *Lathyrus sativus* L. indicates the blue colour of flowers (flore coeruleo), but in so doing the group of white-flowered white-seeded plants is distinguished (b. flore fructuque albo).

Within another domesticated species, *Lathyrus odoratus* L., LINNAEUS considered two "geographical" groups, the Cypriote and the Ceylonese group (a. *L. siculus*; b. *L. zeylanicus*), and pointed out their distinctions in flower colour. Later researchers retained both wild and domesticated Linnaean species of *Lathyrus* on a full scale, but domesticated species were considered since then as fractional, and the genus as subdivided into groups of species (LINNAEUS subdivided the genus into three groups according to the number of flowers – one, two or many).

Peculiarities of systematics of domesticated plants

Systematics of domesticated plants, being an integral part of general plant systematics, has common purposes with the latter, but also a number of specific features. Not only has it a great theoretical importance as a basis for the development of theoretical biology, and research into speciation and the species structure, but also it has great practical importance for solving problems of breeding, introduction and plant use. The subject in this case is the domesticated species, which has a common origin with its closest relatives, namely wild species. On the one hand, they are connected into an integral system, but on the other hand, the domesticated species developed under purposeful artificial selection and differ more or less essentially from their wild relatives by a complex of morphological and biological characters.

VAVILOV (1965) noted that "the study of a large number of samples under cultivation will necessarily reveal the polymorphic nature of species" and considered the species as a system "differentiated into geographical and ecological types and sometimes consisting of an enormous number of varieties". Developing VAVILOV's concept of species, SINSKAYA (1979) considered the species as a "system of populations" and regarded the population as "the lowest, elementary building block of the species". Many Russian researchers considered the species structure as a system of these building blocks, namely populations (e.g., ZAVADSKY 1968, AGAEV 1987). They pointed out that the most important characteristic of populations is their intra-population genetic variability, which manifests itself in several or numerous clearly distinct discrete (qualitative) morphological or other phenotypical characters (polymorphism) (KONAREV 1995).

Taxonomic units in the systematics of domesticated plants

Taxonomic units to recognise these intraspecific changes are intraspecific taxa of different rank.

The traditions of Linnaean systematics were extended to cultivated plants during the past two centuries. As early as in the 19th century, the systematics of cultivated plants began to appear more and more insistently as an independent branch of plant systematics. It became a theoretical basis for agronomists and plant breeders, i.e., all who dealt with cultivated plants.

In the 20th century, botanists proposed special taxonomic categories for cultivated plants. Most frequently, "cultivar" and "group of cultivars" were used (MANSFELD 1953, 1954, and other authors). Likewise, in our country, these were, for example, for the Fabaceae, ZALKIND (1937), GOVOROV (1937), BARULINA (1937), DITMER (1937) and many others. In the 1940-50s, a wide range of extensively elaborated classifications was proposed for polymorphic species of cultivated plants.

The International Code of Nomenclature for Cultivated Plants (ICNCP), first published in 1953 (STEARN 1953), formalised the distinctions between classifications of wild and of cultivated plants and proposed a hierarchy of nomenclatural combinations for different taxa of cultivated plants. This Code legitimised the taxon rank "cultivar", to establish "uniformity, exactness and stability in the naming of agricultural, garden and forestry cultivars."

However, the ICNCP did not separate systematics of cultivated plants from systematics of wild plants, and names of genera and species epithets should conform to the rules of the International Code of Botanical Nomenclature (GREUTER et al. 1994), which regulates nomenclature of wild plant taxa. There is a very deep problem behind this question, and the long-felt need of its detailed discussion now becomes urgent in the scientific community.

At the Third International Symposium on the Taxonomy of Cultivated Plants in Edinburgh in 1998 (cf. ANDREWS et al. 1999), there was a discussion on the advisability of introducing the term "culton" for cultivated plants in analogy to the term "taxon" used in the taxonomy of wild plants. The proponents of the culton concept (HETTERSCHEID and BRANDENBURG 1995; TREHANE et al. 1995) advanced two main arguments in favour of this category:

- A plant, once domesticated, may differ radically from its wild ancestor. It becomes something different not only in a complex of morphological and biological characters, but also often by possessing a different genetic structure.
- The culton is a simpler category, more convenient to use. Its introduction would allow separating the nomenclature of cultivated plants from the hierarchical system of intraspecific taxa expressed in the narrow bounds of the Linnaean binomial system.

We should note, however, what this nomenclatural combination does mean. For example, let us assume that the following information is found on the label of a herbarium sheet:

> *Lathyrus sativus* L. ssp. *sativus* convar. *cyaneus* Smekal. var. *azureus* (Korsh.) Smekal. f. *biflora* Smekal.
> Type:
> K-852 (VIR). Origin.: Asia Minor; reprod.: UES VIR (Ustimovsk Experimental Station, Ukraine, Poltava distr.), 07.06.1988 (WIR).

The species name is not simply a combination. It contains:

- the author's understanding of the species circumscription (the name given by the author);
- the author's understanding of the species structure (intraspecific differentiation);
- each intraspecific taxon corresponds to a complex of characters, inherent only in this taxon. The author legitimates the taxon by its description, diagnosis, outline of the complex of characters of the taxon, and the range of their appearance;
- furthermore, it indicates that this taxon is a branch of evolution.

Necessity of development of systematics of cultivated plants

VAVILOV was one of the first to declare the necessity of complex investigations of species. However, the possibilities of systematics of cultivated plants have increased considerably since that time. Along with classical morphological, anatomical, and biological methods, new methods such as electron microscopy, biochemistry, and genetics, are now at the disposal researchers. These allow elaboration of controversial items in systematics in more detail. The enlargement of capabilities for use of original materials in breeding programmes for different crops brings with it the necessity of further development of systematics to a new, up-to-date level, including the use of recent achievements in several fields of biological sciences.

On the other hand, the creation of a network of national and international genebanks demands special, stringent requirements for the correct systematisation (classification and nomenclature) of the material kept, and for the observation of the international nomenclature rules. Practical experience shows that neglecting these rules will inevitably lead to errors, which result in loss of material. For example, some American genebanks, when accessioning germplasm, use only the genus and species names together with a system of "descriptors", which represents characters by coding them as numerical symbols (scores):

A – Seed colour: (white – 0; red – 1; yellow – 2; etc).
B – Seed shape: (oval – 0; oblong – 1; round – 2; etc).
D – Leaf hairiness: (yes – 0; no – 1; etc).

The nomenclatural combination is often reduced to the Latin name of the genus, for example, oats – *Avena* spp.

An obvious imperfection of this registration system lies in the danger of merely mechanical mixing-up of figures, and in this case, any error is difficult to recognise immediately, and one error would lead to others. We can see an example of this kind of mistake on the cover of the "Report of a Working Group on Avena" (MAGGIONI et al. 1998), which shows a picture of an accession named 'Creole' (France) with yellow seeds, but actually this variety has black seeds. Furthermore, if a genebank curator is not very experienced, he may have difficulties with the coding of a character (e.g., oval *vs.* elongate; oval *vs.* roundish, etc.).

Taxonomic disagreements are a great obstacle for the work of both genebanks and the systematics of cultivated plants as a whole. The underlying reason for such disagreements are different views on the circumscription, structure and criteria of species and intraspecific taxa. As MAYR (1973) noted, "In taxonomy we have almost unlimited differences of opinions on different problems". Thus, different experts have recognised within the genus *Triticum* from one (Löve 1984) to 40 and more species (Bowden 1959).

In another case, two hexaploid oat species, *Avena sativa* and *A. byzantina*, are distinguished by a number of morphological, geographical and ecological characters, but on the other hand, they have two parallel sets of similar morphological characters (cf. Tab. 1). The curators of the oat collection of the Vavilov Institute recognise them as distinct and separate species (Rodionova 1994), while Ladizinsky (1996) considers them as a single species, *A. sativa*. As a result, the same sample from the same collection site may be classified as different species in different genebanks.

Tab. 1: Similarities and distinctions between two *Avena* species

Species	Traits		
	Morphological	Ecological	Geographical
Avena sativa L.	• complex of traits characteristic for each species; • parallel rows of similar traits within both species	mesophyte	Northern Europe
A. byzantina C. Koch		xerophyte	Southern Europe (Mediterranean)

What is necessary to develop the systematics of domesticated plants?

1. To study the complexities of species using all methods including biochemical analyses, electron-microscopy, genetics, etc., as advocated by Vavilov;
2. To evaluate the possibilities for gene transfer and thus use more sources for breeding:
3. To correct the nomenclature in order to improve the maintenance of samples in genebanks;
4. To analyse the reasons and sources for disagreements between taxonomists and to strive for agreement.

The Vavilov Institute of Plant Industry maintains and develops traditions of biosystematics (differential systematics) of cultivated plants. In particular, the systematics of several genera, species and subspecies of the family Fabaceae have been elaborated in recent years (*Cicer* L., *Lathyrus* L. subgen. *Cicercula* (Medik.) Czefr., *Vicia sativa* L., etc.).

When elaborating the systematics of the subgenus *Cicercula* of the genus *Lathyrus*, in addition to the basic morphological-geographical method, a number of other methods have been used such as electron microscopy, anatomy, and biochemistry. The seed collection of the Vavilov Institute, and herbarium collections of the Vavilov Institute (WIR), the Komarov Botanical Institute (LE) and other botanical institutions were included in this study. Herbarium work is the most essential step in every taxonomic investigation (MCALISTER 1998), since it gives the opportunity for a comparative study of a great number of specimens from different origins. The worldwide herbarium collection of the Vavilov Institute contains over 500 specimens of 51 species of the genus *Lathyrus*. Through this research the circumscription, structure and status of the group of species, which earlier were included by different authors in the section *Cicercula* (Medik.) Gren. and Godr. or in the subgenus *Lathyrus*, were revised accordingly (KUPICHA 1983). We consider this group of species as a separate subgenus, which includes 21 species. Four subsections and three series are distinguished within it, mainly by a complex of morphological and anatomical characters of flowers, pods and seeds, the structure of the vascular tissue in the stem and the character of the seed coat. The evolution of the genus followed the path of separation of annual from perennial species. The increasingly arid environment played a key role in reducing the life cycle in a number of species and in the development of a complex of specific morphological-anatomical characters of the vegetative and generative organs. A system of intraspecific taxa has also been elaborated for polymorphic species. The most complex intraspecific differentiation is found in the domesticated species *Lathyrus sativus*.

In recent years, systematic investigations have often been based on the application of a single method. Completely new branches of systematics have been established, such as ecosystematics (MELIKYAN 1984), molecular systematics (DOYLE 1992), gene systematics (ANTONOV 2000) and others. Concentration on one particular method and lack of appreciation of others often lead to errors in phylogenetic reconstructions, the latter being the main purpose of systematics. “A system is meant to reflect the results of evolution, and evolution is a permanent search of the new” (SKVORTSOV 1979). A taxon will enter life’s arena only when it finds new ways to live. Consequently, it is not possible to work out some uniform, universal rules for systematic constructions. Systematics is a creative process, it is an interpretation, and although based on concrete data from many sciences, it can be generated only by intellect. “Modern systematics, being a complex and synthetic discipline, … cannot ‘exhaust itself’, but rather the opposite because, due to its exclusive position in the system of sciences, the circle of problems limiting the scope of systematics activity is perpetually enlarging” (TIKHOMIROV 1979).

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Multiple domestications and their taxonomic consequences: the example of *Phaseolus vulgaris*

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Abstract

The evolutionary history of *Phaseolus vulgaris* is important to those working on its genetic resources, but is not reflected in its infraspecific taxonomy. Genetic isolation of wild populations between and also within Middle and South America has resulted in morphological and molecular differentiation. Populations from northern and southern ends of the range are assigned to different gene pools, though intermediates occur in intervening areas. Chloroplast haplotypes suggest three distinct lineages of wild beans and several intercontinental dispersals. The species was domesticated independently in both Middle and South America, probably several times in Middle America. This, together with further differentiation under human selection, has produced distinct races among domesticated beans. The informal categories of wild versus domesticated, gene pool, and race convey the evolutionary picture more clearly than the formal categories provided by the Codes of Nomenclature for wild or cultivated plants.

Introduction

One active debate in taxonomy today concerns whether or to what extent taxonomy should reflect evolution. Above the species level, cladistic principles currently predominate, but below the species level, cladistics has had much less impact on classification, for two reasons. Firstly, at this level there is usually too much parallel evolution in morphological characters and too little variation in molecular characters to generate a cladistic classification with which one may feel confident. Secondly, hybridisation is often important at and below the species level, and cladistics is notoriously bad at dealing with the consequent reticulations in evolutionary lineages.

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Classification involves assignment of the objects being classified into classes, followed by arrangement of those classes in an order that reflects a principle of some kind, whether the arrangement is purely artificial (e.g., alphabetical), is based on overall similarity (natural), or represents putative evolutionary relationships (phylogenetic). The International Code of Nomenclature for Cultivated Plants (TREHANE et al. 1995) provides only two categories for classifying variation within any given cultigen: cultivar and cultivar-group. This suffices for constructing an organised catalogue of names for commercial purposes, but is insufficient to reflect the hierarchy of variation developed through human selection in many crops, as discussed previously for *Capsicum* pepper, faba bean, peanut and banana (PICKERSGILL 1986, PICKERSGILL and KARAMURA 1999).

Previous discussions of the taxonomy of cultivated plants have not considered explicitly the consequences of multiple domestications of the same species in different parts of the range of its wild ancestor. Different parts of the genetic diversity of the wild progenitor are thereby included in different lineages within the crop: a fact of potential significance to plant breeders and curators of gene banks, who are important users of crop classifications. On the other hand, human selection may produce parallel changes within each lineage and hybridisation may result in gene exchange between lineages, so that it may be neither feasible nor useful to distinguish these lineages in practice.

Common bean (*Phaseolus vulgaris* L.) is an example of a species that has clearly been domesticated more than once. It may therefore be used as a case study of the extent to which taxonomy of a crop can or should reflect its evolution under domestication.

Multiple domestications in *Phaseolus vulgaris*

Wild common beans range from northern Mexico to north-western Argentina (GEPTS and DEBOUCK 1991). Mesoamerican wild beans differ from those of the Andean region in various morphological characters (VANDERBORGHT 1983), some of which may relate to ecological differences. Small-seeded Mesoamerican beans occur in disturbed shrubby vegetation; large-seeded Andean beans in less disturbed moister and cooler forests (KOENIG et al. 1990). Wild beans from the two continents are reproductively isolated, at least partially, by complementary lethal genes (KOINANGE and GEPTS 1992), which may have developed as a by-product of independent evolution in each continent. Similar genetic divergence has occurred in isozymes (GEPTS 1990), phaseolin seed proteins (GEPTS et al. 1986, GEPTS 1990), nuclear DNA, both RFLPs (BECERRA and GEPTS 1994) and AFLPs (TOHME et al. 1996), and mitochondrial DNA (KHAIRALLAH et al. 1992). Domesticated common beans show differences in morphology, isozymes, phaseolins and nuclear and mitochondrial DNA polymorphisms which parallel those in wild beans, and strongly suggest that beans were domesticated independently in Middle and South America, from local wild types (GEPTS et al. 1986, GEPTS 1990, KHAIRALLAH et al. 1992, BECERRA and GEPTS 1994).

Tab. 1: Haplotypes found in landraces of common bean and their geographic distribution in wild common bean

Haplotype	Distribution in domesticated beans	Geographic distribution in wild beans
C	Andean gene pool (Races Nueva Granada, Peru and Chile)	Central and southern Peru
I	Mesoamerican gene pool (Races Mesoamerica and Guatemala)	Southern Mexico; western, central and eastern Guatemala; eastern Honduras; central Colombia
K	Mesoamerican gene pool (Races Mesoamerica and Durango)	Northern Mexico; west-central and southern Mexico
L	Mesoamerican gene pool (Races Mesoamerica, Durango and Jalisco)	Western and central Mexico; western Guatemala; Costa Rica; Colombia

It has also been suggested that *P. vulgaris* was domesticated more than once in each continent. In Mesoamerica, analysis of RAPDs (BEEBE et al. 2000) separated domesticated beans into groups which corresponded well to the three Mesoamerican races (Mesoamerica, Durango, Jalisco) recognised by SINGH et al. (1991). BEEBE et al. (2000) also recognised a fourth race (Guatemala) and considered that their RAPD data implied two or more domestications from distinct wild populations. However, Mesoamerican domesticated beans nearly all carry the S type of phaseolin even though more than 15 types of phaseolin are present in Mesoamerican wild beans (GEPTS and DEBOUCK 1991). GEPTS (1998) therefore argued that, in Mesoamerica, common beans were domesticated once only, in west central Mexico (Jalisco) where S phaseolin predominates among local wild beans, then diversified into the present-day races. In South America, Andean landraces have been classified into three further races (Nueva Granada, Peru, Chile) thought, like the Mesoamerican races, to represent distinct evolutionary lineages (SINGH et al. 1991). Several different phaseolins are present in these landraces, so GEPTS (1998) suggested multiple domestications in the Andean region. However, the DNA of Andean landraces has diverged very little, so BEEBE et al. (2001) argued that the three Andean races must have diversified after domestication.

Chloroplast DNA has some advantages over nuclear DNA in studies of the domestication and spread of crop plants. It does not recombine, and is usually inherited through one parent only, so heterozygosity does not complicate the analyses. Contrary to early reports, chloroplast DNA, particularly the non-coding regions of the molecule, often does vary within a species.

Chloroplast DNA and domestication of common bean

We amplified 10 different regions of chloroplast DNA and studied them by sequencing and/or restriction digestion (for details, see CHACÓN S. 2001). In a sample of 158 accessions of wild common bean from the CIAT gene bank collection, we identified 16 chloroplast haplotypes, each characterised by at least one unique feature, usually a nucleotide substitution. A network was constructed which linked these haplotypes by single mutational steps (Fig. 1), often through inferred haplotypes that may now be extinct, or not yet collected, or simply not represented in our sample.

Only four of the 16 haplotypes present in wild common bean occur in domesticated beans, illustrating the familiar founder principle or genetic bottleneck associated with domestication. Table 1 shows that landraces originating in Mesoamerica differ in chloroplast haplotype from Andean landraces. The three haplotypes present in Mesoamerican landraces are found only in wild beans from Mesoamerica and Colombia, while the single haplotype present in Andean landraces occurs only in wild beans from central and southern Peru. This provides further evidence of independent domestication of common bean in Mesoamerica and the Andes. It also agrees with the DNA studies of BEEBE et al. (2000, 2001) in demonstrating greater molecular diversity in Mesoamerican landraces than in Andean landraces.

To investigate further whether there were more than two domestications of this crop, it is necessary to look more closely at the frequencies and distributions of haplotypes in Mesoamerican common beans (Tab. 2 and 3).

Tab. 2: Chloroplast haplotypes in races of domesticated common bean (figures represent numbers of accessions; * haplotype resulting from interracial introgression)

	Haplotype				Total
	C	I	K	L	
Mesoamerican	**0**	**7**	**65**	**20**	**92**
Race Mesoamerica	0	4	45	5	54
Race Durango	0	0	18	7	25
Race Jalisco	0	0	1*	8	9
Race Guatemala	0	3	0	0	3
Andean	**30**	**0**	**1***	**0**	**31**

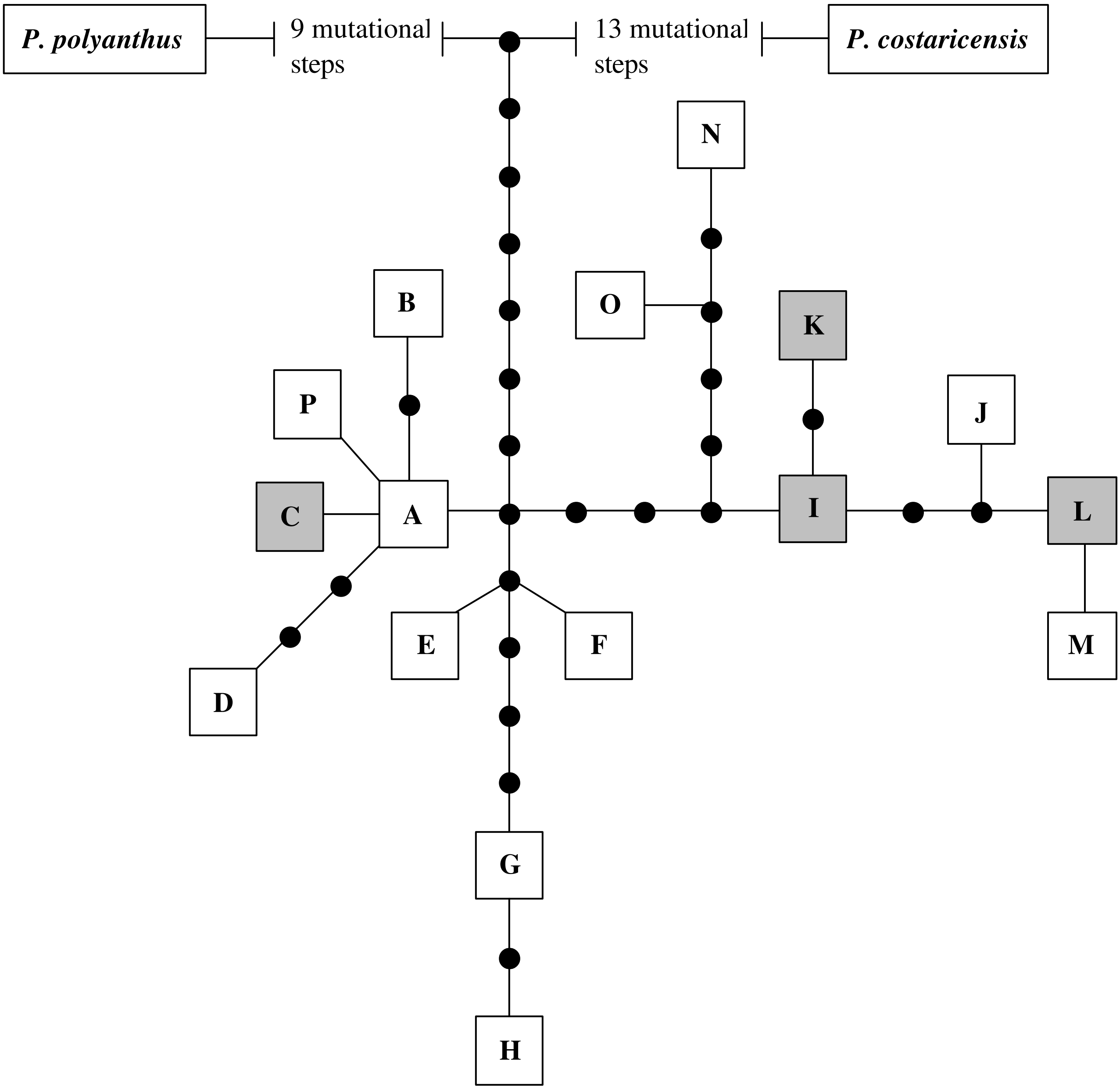

Fig. 1: Network showing relationships among chloroplast haplotypes in *Phaseolus vulgaris* (missing haplotypes indicated by solid circles, haplotypes found in both wild and domesticated beans by shaded boxes, haplotypes found only in wild beans by non-shaded boxes; network rooted by the wild species *P. polyanthus* and *P. costaricensis*).

Tab. 3: Distribution amongst Mesoamerican wild beans of the chloroplast haplotypes found in Mesoamerican races of domesticated common bean and their co-occurrence with other haplotypes
(Mexican states ordered from north to south, figures represent numbers of accessions)

COUNTRY	**Haplotype**									**Total**
or State	A	B	G	I	J	K	L	N	O	
MEXICO	**26**	**6**	**0**	**8**	**4**	**12**	**7**	**1**	**2**	**63**
Chihuahua	0	0	0	0	0	1	0	0	0	1
Durango	0	0	0	0	0	4	0	1	0	5
Nayarit	1	0	0	0	0	0	2	0	1	4
Jalisco	9	1	0	0	2	1	3	0	0	16
Mϑxico	0	1	0	0	0	0	1	0	0	2
Puebla	1	0	0	0	0	1	0	0	0	2
Oaxaca	0	1	0	1	0	5	1	0	0	8
Chiapas	0	0	0	7	0	0	0	0	0	7
GUATEMALA	**0**	**0**	**7**	**7**	**6**	**0**	**1**	**0**	**0**	**21**

Haplotype K is the most frequent haplotype among Mesoamerican landraces and predominates in Races Mesoamerica and Durango. Amongst wild beans, it has a disjunct distribution, occurring in southern Mexico (Oaxaca, Puebla and rarely, Jalisco) and also in northern Mexico (Durango and Chihuahua).

Early archaeobotanical remains of domesticated common bean are found in or near both of these areas (Kaplan and Lynch 1999). This suggests that wild beans with haplotype K were domesticated in southern Mexico, northern Mexico, or both, to give rise to Race Mesoamerica, now characteristic of warm humid areas, and Race Durango, now associated with cool semi-arid highlands.

Haplotype L is the predominant haplotype in Race Jalisco, which is characteristic of the humid highlands of central and southern Mexico (Singh et al. 1991, Beebe et al. 2000). It occurs also in Races Mesoamerica and Durango. Among wild beans, it is present in Jalisco, occurs also, though less frequently, in wild beans from Oaxaca and Guatemala, but is absent from northern Mexico.

Haplotype I is the only haplotype present in Race Guatemala, a race of climbing beans centred on Guatemala and the adjacent Mexican state of Chiapas. It is the only haplotype that we have found in wild beans from Chiapas, is one of the most frequent haplotypes in wild beans from western and central Guatemala, and is present, though not common, in wild beans from Oaxaca.

These data support BEEBE et al. (2000) in suggesting that at least three of the four Mesoamerican races were domesticated independently: Race Jalisco in Jalisco; Race Guatemala in Guatemala or Chiapas; Races Mesoamerica and Durango in northern and/or southern Mexico. If there was only a single domestication, as GEPTS (1990) argued, then it probably occurred in Oaxaca rather than Jalisco, since in Oaxaca the relevant chloroplast haplotypes all occur and S phaseolin is also present.

Infraspecific taxonomy of *Phaseolus vulgaris*

Three particularly significant events have occurred in the evolutionary history of *P. vulgaris*. Firstly, early intercontinental dispersal resulted in genetic isolation of wild populations in the two continents, so they differentiated into what have been called the Mesoamerican and Andean gene pools. Secondly, beans in each of these gene pools were independently domesticated, probably in more than one location in the case of Mesoamerica. Thirdly, domesticated beans diverged and diversified under human selection into different ecogeographic groups (races), different agronomic groups (e.g., climbing or bush beans) and different use groups (popping beans, black beans, navy beans, pinto beans, etc.). The question then arises, should any or all of these events be recognised in the infraspecific classification of *P. vulgaris* and if so, how?

Intercontinental dispersal and divergence of gene pools

The many differences between Mexican and Andean wild beans have led to their being recognised as distinct varieties (see DEBOUCK 1991 for further discussion). This provides a formal taxonomic rank for the informal category of gene pool.

Wild beans from Ecuador and northern Peru are morphologically intermediate between those of the Mesoamerican and Andean gene pools (DEBOUCK et al. 1993), and combine isozyme alleles characteristic of both gene pools (GEPTS 1993). They are genetically unique in their RAPD and AFLP patterns (FREYRE et al. 1996, TOHME et al. 1996) and in their mitochondrial DNA (KHAIRALLAH et al. 1992). They also carry an apparently ancestral type of phaseolin (KAMI et al. 1995). It has been suggested that these populations are relicts of the ancestral stock from which the Mesoamerican and Andean gene pools are derived (KAMI et al. 1995, TOHME et al. 1996). Wild beans from Costa Rica south to Colombia are also morphologically intermediate (SINGH et al. 1991), while a study of AFLPs showed a genetic continuum between wild beans from the northern and southern ends of the range (TOHME et al. 1996).

Under the Rules of the International Code of Botanical Nomenclature, populations that are intermediate between two varieties must be included in one or the other (which causes problems in distinguishing between the varieties) or else a third variety must be created for the intermediates. The advantage of an informal category such as gene pool is that the situation can be described without every accession having to be placed in a gene pool. In other words, the Mesoamerican and Andean gene pools can be recognised, together with the Ecuadorian / north Peruvian relict of the ancestral gene pool if desired. Wild beans from intervening areas can be treated in whatever way the available information seems to warrant. For example, they may be left as intermediates or placed in additional gene pools. Furthermore, gene pools, unlike taxonomic varieties, do not have to be morphologically distinguishable. Gene pool is a category used to express genetic differentiation, not necessarily a category that can be recognised in the field.

The chloroplast haplotypes define three lineages of wild *P. vulgaris* (Fig. 1). These agree only partially with the picture based on gene pools. Haplotypes E and F are found in the putatively ancestral relict populations of Ecuador and northern Peru and seem to represent early derivatives of a lineage that then spread into Central America (haplotypes G and H). No elements of this lineage seem to have been domesticated. A second lineage, bearing haplotypes I to O, contains wild beans of the Mesoamerican gene pool and some of the intermediates. However, the third lineage (haplotypes A to D and P) combines morphologically distinct wild beans from both Mesoamerican and Andean gene pools. These chloroplast data are potentially significant with regard to both conservation and utilisation of genetic resources of wild beans. For example, Mesoamerican beans with haplotypes A, B and P appear to have evolved independently of Mesoamerican beans with haplotypes I to O for a long time so may carry significantly different diversity. They should therefore be prime candidates for both conservation and evaluation. However, we consider it premature to try to represent the chloroplast lineages in either formal or informal classifications, at least until some nuclear phylogenies are available and the chloroplast lineages checked for congruence with these.

Domestication

As in many species that include a crop and its conspecific wild progenitor, wild and domesticated common beans are usually placed in different subspecies, ssp. *aborigineus* and ssp. *vulgaris* respectively (see POLHILL and VAN DER MAESEN 1985 for discussion of this treatment for grain legumes in general, including *Phaseolus*). However, subspecies ranks above variety in the taxonomic hierarchy, so if the Mesoamerican and Andean gene pools are treated as varieties, they cannot then be subdivided into subspecies. Moreover, at whatever rank the gene pools are treated, four (not two) names at a lower rank would be needed to classify the wild and domesticated beans within each gene pool. The current Code of Nomenclature for Cultivated Plants (TREHANE et al. 1995) recommends that cultivated plants below the rank of genus should no longer be named under the provisions of the International Code of Botanical Nomenclature. It further states, in article 1, that at the level of species or below, cultivated plants should be named in accordance with the Botanical Code "if, and only insofar as, they are identifiable with botanical [i.e., wild] taxa in those ranks." Since a domesticated subspecies is, by definition, not identifiable with any wild subspecies, use of ssp. *vulgaris* to distinguish domesticated from wild beans seems to violate the intentions of the Cultivated Code. However the Cultivated Code provides no alternative category for this purpose, leaving the vernacular phrases "wild common bean" and "domesticated common bean" as the only solution. This aspect of the Cultivated Code certainly seems to need either clarification or revision in subsequent editions.

The independent domestications in Mesoamerica and South America could be represented by the more lengthy vernacular phrases "Mesoamerican domesticated beans" and "Andean domesticated beans". However, this becomes very cumbersome when extended to the independent domestications within Mesoamerica. The only formal category available is that of cultivar-group, which we consider more appropriate for the products of differentiation within the major lineages of domesticated beans.

Differentiation under human selection.

Human selection has developed striking but parallel ranges of seed types, growth habits and ecological adaptations in Mesoamerican and Andean domesticated beans (SINGH et al. 1991). SINGH et al. (1991) used the informal category "Race" for what they regarded as distinct lineages among domesticated beans in each region. The only category provided by the Cultivated Code is cultivar-group. Race Mesoamerica, Race Durango, etc. would then become Mesoamerica Group, Durango Group, etc. The Cultivated Code explicitly permits cultivars (and, presumably, landraces) to belong to more than one cultivar-group simultaneously. Habit types would therefore appear as Climbing Group, Bush Group, etc., and use types as Popping (or NuZa) Group, Snap Bean Group, Navy Group, etc. Insofar as the races of SINGH et al. (1991) reflect evolutionary lineages, then once the race of an accession is known, deductions and predictions can be made about its other features. For example, we predict that beans belonging to any of the three Andean races will carry chloroplast haplotype C, while beans belonging to Race Mesoamerica will probably carry haplotype K. But cultivar-groups based on characters such as habit type or seed colour are artificial constructs, designed for particular groups of users, and permit no prediction about other characters of those cultivar-groups. For example, Dutch cultivars of snap bean may carry phaseolin T, hence be of Andean origin, or phaseolin S, hence originate from Mesoamerica (ZEVEN et al. 1999).

Effects of dispersal and hybridisation

To qualify for taxonomic recognition, a taxon must persist over time. Both Mesoamerican and Andean races have been dispersed widely by man subsequent to their domestication. They may now be grown together in the same area, ecological differences notwithstanding, and may then intercross. There has therefore been ample opportunity for distinctions between gene pools or races to become blurred by hybridisation. This has not in fact occurred on any large scale. For example, BEEBE et al. (2000) studied RAPD banding patterns in 269 Mesoamerican landraces and found that nine had several bands characteristic of Andean landraces so probably resulted from introgression. This is a very small proportion of the total sample. KHAIRALLAH et al. (1990) studied isozymes and mitochondrial DNA in beans from farmers' mixtures in Malawi, where beans from Mesoamerican and Andean gene pools have been cultivated together for at least three centuries, and found that most lines could be placed clearly in one or other gene pool. Lines showing evidence of inter-gene pool hybridisation were very rare. ZEVEN et al. (1999) failed to distinguish gene pools or races in a core collection of Dutch common bean when they used 14 characters of predominantly horticultural significance, but could classify them into gene pool and race when they used the appropriate diagnostic characters.

There is therefore sufficient justification for recognising taxa corresponding to wild versus domesticated beans, different races within domesticated beans, and possibly different gene pools. However, neither the Botanical nor the Cultivated Code provides adequately for recognition of taxa that reflect or cut across the divide between wild and cultivated plants.

Conclusions

Names for wild common beans are governed by the Botanical Code. This provides two categories, subspecies and variety, to treat infraspecific differentiation. One or other of these could be used to provide formal names for the wild beans in the Mesoamerican and Andean gene pools, though the requirement that every plant be classifiable into a named taxon at a particular rank causes problems when dealing with intermediates, as STACE (1986) has already noted. The lineages of chloroplast haplotypes do not correspond well with morphological differences among wild beans. Integrating molecular information on evolutionary lineages with formal taxonomic classifications is currently a problem at many levels of the taxonomic hierarchy.

In domesticated beans, as in other crops, human selection after domestication has partitioned variation within the domesticate into different use groups, different agronomic groups, etc. These are treated, under the Cultivated Code, as different cultivar-groups. How satisfactory this is depends on the complexity of the variation and the number of cultivar-groups to be discriminated. For example, cultivar-group names such as White Headed Cabbage or Savoy Headed Cabbage (JANSEN et al. 1994) are in some danger of becoming as lengthy as the pre-Linnaean phrase names which were abandoned in favour of the simpler binomial system.

When a crop was domesticated more than once, as in common bean, this cannot easily be reflected in its taxonomy, because the Cultivated Code provides only the single category of cultivar-group to encompass all variation between genus or species and cultivar. Growers or consumers of cultivated plants do not need names that reflect the evolutionary history of what they are growing or eating. Probably only those concerned with conservation and utilisation of genetic resources of a crop really need such information. Since we have shown that evolutionary history of a crop cannot be adequately reflected using the categories provided by the Cultivated Code, informal categories will no doubt continue to be invented and used. In *Phaseolus vulgaris*, the informal categories of gene pool and race have served well to communicate our present understanding of evolution and genetic diversity in this species. Whether this will continue to be true when we have the more detailed phylogenies which DNA studies promise to deliver, only the future will tell. However, the data currently available suggest that there may be both challenges and surprises ahead.

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Ethnobotanical studies on cultivated plants. A theoretical approach (Studies on Ethnobiodiversity, 6.)

A. SZABÓ T. [1]

In memory of Rudolf Mansfeld

Abstract

In continuation of former studies on ethnobiodiversity the following (theoretical) questions are briefly examined in the paper:

- May ethnobotany be useful in understanding crop-plant and human (biological, linguistic, cultural, religious) evolution in a time of raising ethnocultural conflicts?
- Which possibilities are offered by ethnobotany in promoting mutual ethnocultural empathy and understanding?
- Is it possible to integrate ethnobotanical concepts, the evolution of man-and-plant relations with emerging theories of general (biological, cultural) evolution?
- How the science of ethnobotany really emerged in form of an independent printed book based on dedicated and conscious field studies?
- Are the basic concepts of ethnobotany well defined?
- Is the North American ethnobotanical approach the right model to follow?

Motto: No perfect discovery can be made upon a flat or a level … BACON (1605, cf. WILSON 1998)

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Introduction

Modern molecular biology is currently spending huge money on genetically modified organisms (GMOs), neglecting almost completely traditional ethnocultural knowledge on plants. Non-governmental organisations (NGOs) are spending another good money to destroy GMOs. The ultimate absurdity of this approach resides in the fact that modern crop science is based fully on ethnobotanical experience preserved mostly *in situ* in the poorest countries of the world. Modern science was unable to create not even a single (major or minor) crop. Commemorating RUDOLF MANSFELD, who "emphasised the necessity to consider all botanical aspects for taxonomic and evolutionary conclusions", is a good opportunity to meditate on different neglected levels in (co-)evolution of agricultural and horticultural crops and cultures (MANSFELD 1959 n.c. [2], STUBBE 1962 n.c., SCHULTZE-MOTEL et al. 1986 n.c., HANELT and INSTITUTE OF PLANT GENETICS AND CROP PLANT RESEARCH 2001).

Plant cultivation needs human skills quite different from those needed for hunting, and resulted very probably in different types of human behaviours and adaptations. This assumption is not supported now by good research. Interactions between crop evolution and specific human co-operative behaviour (including linguistic, ethnic, social, cultural and even religious aspects) are rather neglected. The study of neurobiological backgrounds of historical, comparative, and evolutionary ethnobotany seems to be a promising science field, accordingly.

We are all aware that ethnobotany will not give explanations and will not solve the problem of many traditional ethnic, economical/ecological and cultural conflicts causing so many tragedies in the 20th and even in the first year of the 21st century. But we also know (or at least feel) how dangerous is the mutual lack of empathy and understanding in managing difficult and complex questions related with competition for resources, sustainability, ethnicity, society and culture. The Afghan-case is relevant is this respect (VAVILOV and BUKINICH 1929, TANI and SAKAMOTO 1987, KAWAHARA 1987, MATSUI 1987). This zone of the first major ethnocultural conflict of the new Millennium was and remains being of major interest for genetic resource explorations (PISTRICK and MAL'CEV 1998, with further references).

Looking both from a botanical and from a (somewhat) philosophical point on the evolution of plant-and-man interactions, it is worth to note that the first great paradigm shifts in understanding these interactions are relatively recent: the "Genetic Laws of Nature" (FESTETICS 1819 n.c.) and factorial inheritance (MENDEL 1865 n.c.), first working concepts on evolution (DARWIN 1859, 1863 n.c.), the science on origin of crop plants (A. DE CANDOLLE 1883 n.c.), the germplasm ('Keimplasma') concept (WEISMANN 1894, n.c.), ethnobotany as a new science (HARSHBERGER 1896), the ge-

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[2] "not cited": due to space reasons, some references are not provided in the references section

netic resource and gene bank concepts (VAVILOV 1927 n.c., HAWKES 1994) emerged during the last 200 years. Understanding the material base of human (and plant) variability on molecular level began practically in the last 50 years (WATSON et al. 1953 n.c.). First genome sequences were published in 2000 for *Homo* and *Arabidopsis* (n.c.). Time is ripening now for new paradigm shifts in understanding interrelations between crop evolution, group knowledge on crops (crop ethnobotany) and human (ethnocultural) evolution, including a phenomenon named here "human nano-evolution", i.e., supposed differential reproduction of couples carrying specific membrane receptor mutations connected with plant food recognition abilities, communication, co-operation and other socio-cultural skills.

Main questions

Our main question is: "May ethnobotany be useful in understanding human (biological, linguistic, ethno-cultural, religious) micro- and nano-evolution?" And, if the answer is "Yes", the next question is: "Which are our possibilities and limitations in promoting a better, worldwide and mutual understanding in these topics?"

There is a further intriguing question: "Is it possible to integrate ethnobotanical concepts in those of J. MAYNARD SMITH and E. SZATHMÁRY (1997) regarding major transitions in evolution, as well as in that of V. CSÁNYI (1999, CSÁNYI and KAMPIS 1991, etc.) regarding integrative human ethology?"

The theoretical base of these questions is the assumption that niche segregation during human evolution was based mainly on food preferences and feeding behaviour, associated perhaps with many and still undiscovered specificities in the molecular evolution of the enzymes, membrane receptors, etc., especially in our sensory organs, brain and the digestive tract.

It is a conditio sine qua non in these studies to keep in mind that biological diversity among living entities, including humans, is a fact of evolution to be studied, while human equality is a moral need and a value to be respected (DOBZHANSKY 1973).

Theoretical issues

The available ethnobotanical literature has been reviewed in search of theoretical backgrounds and definitions. Special attention was paid to Hungarian agrobiodiversity and ethnobotany studies (GYULAI 2000, I. SZABÓ et al. 2000, with further references). Different concepts related to possible group selection factors acting during plant domestication and cultivation (ethnicity, ethnic knowledge on plants, ethnobiodiversity, etc.) were also considered.

Regarding the accumulation of information in biological systems sensu lato (i.e., including social systems), it is clear that new information is accumulated during evolution in different, isolated self-reproducing compartments. These compartments were regularly isolated/connected first by chemical bounds (in the RNA world), later by membranes and cell walls (in proto-cells, cell-organs, pro- and eukaryotic monocellular organisms), dermal structures (in multicellular organisms), complicated receptor systems (in reproductively isolated but still hybridising species), up to different languages, beliefs and cultures in ethnically and/or culturally isolated, but internally and externally interacting societies.

It is worth to note here that ethnobotany is a science interested mainly not in isolation, but in integration mechanisms acting on the top of this evolutionary process.

The essence of botany is to accumulate knowledge on plants: to describe and understand the plant world on different sites and especially around different human societies. The share of knowledge connected with plant use and finally with cultivation (including the mass cultivation of bacteria, algae, fungi, etc.) was, is and will be a human integrative issue.

The isolation mechanisms in this process, i.e., the very nature of the (relative, social) reproductive isolation between human groups and societies are poorly understood. The nature of ethnicity (language and culture) seems to be decisive. Recent books and papers on the subject (GOULD 1999, GUIBERNAU and REX 1999, MANN 2001, SMITH 1999, SOLLORS 1996, STUMPF 2001, etc.) demonstrate accordingly a raising interest toward language and ethnicity, but there are many signs of poor understanding (and sometimes even a lack of honesty) in the discussions. Since ethnicity is strongly connected with lasting and deep historical traditions, the North-American (US) model of ethnicity is a particular case not suited for generalisations. So we may presume, for example, that the lack of traditional ethnobotanical background among white Anglo-Saxon protestants from the USA is correlated perhaps more with misunderstanding than with understanding of ethnic phenomena.

The content of the word "ethnicity" itself seems to be ill-defined and often erroneous for historic reasons. This is strange, because ethnic phenomena are very influential and important. The first World War started in part due to Austro-Hungarian lack of ethnic empathy and understanding (1914) and this is true for the Second World War as well (1939), not mentioning here the ethnic problems in Great Britain, the Basque problem in France and Spain, the Hungarian problem in Central-Europe, the Balkan conflicts (1990-), the Chechen, Afghan, Palestinian and many more cases.

Ethnically complex territories often harbour unique plant genetic resources. It is worth to remember here that some "indicator species", for example the cultivated Einkorn (*Triticum monococcum*), are quite regularly "associated" with ethnically sensitive areas (SZABÓ 1978a, 1981, 1990/92, 2000, etc.). In this respect the (gene)ecological, economical and environmental importance of ethnic phenomena are above doubts. Major gene-ecological disasters both on plant side (full genetic erosion) and on human side (genocidium) are often rooted deeply in grave misinterpretation and mistreatment of ethnicity, in lack of understanding the importance of ethnobiodiversity.

In the first approach, the plant factor is a minor component in ethnic conflicts. However, the management of crops, the agriculture is a basic factor in the final approach because this is the ultimate source of biological energy needed for a sustainable society. The danger of food shortage and the lack of sustainability are important sources of controversies. Globalisation causing the erosion of local ethnic and cultural traditions and followed by the erosion of plant genetic resources may even amplify some of these controversies.

Many simple questions were perhaps never formulated. For example: has the affection toward plants a gender-linked component or is the common experience of ethnobotanists almost everywhere in the world concerning a better plant knowledge among women just culturally determined? Looking on the "Major Transitions in Evolution" (MAYNARD SMITH and SZATHMÁRY 1997) we may presume that group knowledge on plants contributed to the evolution of structured language and communication. There is a growing set of evidences that these human skills have gender-linked components.

Another example for intriguing questions is, whether plant gathering and plant cultivation was correlated on group scale with the evolution of different brain mechanisms and consequently with components of individual and group behaviour in nomads, hunters and warriors? This possibility is again not supported yet by any good research. Consequently, the time is still not ripe to integrate ethnobotany with general human ethology preferred by CSÁNYI (1999).

Definitions

The plant side

Spontaneous (wild) plant, economic plant, forage plant, food plant s.l. (including medical food), domesticated plant, cultivated plant are quasi-hierarchical categories, reflecting different degrees of plant interactions with human groups. The "cultivated" plant category *sensu stricto* includes only members totally dependent from human interactions. Such interactions began in the pre-human phase of evolution, as a continuation of co-evolution between the animal and the plant world. However, with the emergence of plant cultivation, the interaction became gradually conscious, and consequently asymmetrical.

On the human side arrived a new information category: the social (group) knowledge related to plant use, domestication and finally large-scale cultivation.

What really happened on the plant side is still not clear. It is traditionally and generally recognised by Linnaean botany to exclude cultivated plants from traditional (floristic, taxonomic) treatments. We have two different "Codes" for the two (different?) phenomena. We just hope that the scientific reasons for the differences will be revealed by genomics (i.e., looking on the physical sequences, the "orthography" of DNA molecules) and genematics (looking on the "grammar" and "mathematics" of the genome). Genomics is an accepted field now. Genematics remains to be established (SZABÓ 1992).

Food plant

In a broad sense, every plant producing substances used (raw or prepared) in human nutrition may be defined as food plant.

Spontaneous food plants pre-adapted for cultivation probably spread first spontaneously around disturbed early human settlements generating perhaps an early "vege-culture" based on green biomass use. "Green food gathering practice" is rooted deeply in a pre-human evolutionary phase. This practice re-emerged perhaps repeatedly well before the "Neolithic Revolution", i.e., before the advent of agriculture based mostly on dry seeds. The study of "vege-cultural" domestication processes is rather neglected; the process itself is poorly understood and insufficiently documented. A direct contact with past (primitive) practice is still observable even in Europe, e.g., around poor gypsy colonies feeding frequently with spontaneous weed (*Chenopodium, Atriplex, Amaranthus*, etc.) green-mass prepared as food during summertime (PÉNTEK and SZABÓ 1985).

Crop plant

The most important cultivated food plants evolved during (and after) the Neolithic Revolution. Some plants producing specific secondary metabolites were used originally for healing, but became later regular food (e.g., *Petroselinum hortense*). Some taxa remained of marginal importance or followed a backward evolution, being once cultivated, but now growing mainly as wild weeds, e.g., the forms of *Portulaca oleracea*, or the "rockets, the *Eruca, Coronopus* and *Diplotaxis* species" (PADULOSI 1995). These neglected crops are "living fossils of vege-domestication."

Newly domesticated food plant species without an ethnobotanical prehistory are surprisingly few, if any. The sugar beet (*Beta vulgaris* convar. *saccharata*) is the last economically important new "vege-crop" evolved during the 19th century, but the beet itself (*B. vulgaris* convar. *vulgaris*) has a very old ethnobotany. The triticale (Triticosecale) emerged as a new seed crop in the mid 20th century from artificial wheat × rye hybrids and has a very rudimentary ethnobotany (only some folk names), but the parent species/genera have deep ethnobotanical roots.

The human side

Humans interacted with plants not just on individual, but mostly on group level. A double-faced group selection occurred probably during domestication: the most explorative human groups selected the best pre-adapted plants/animals for a given task or environment. Successful topogenodemes had an increased reproductive success and could co-evolve better on both sides.

On the human side, the leading force of the co-evolution was the information storage and flow along the line of common descent, language and culture, i.e., along tribal and "proto-ethnic" lines. Human group preferences can strongly influence plant characters. Traditional group knowledge on plants with given "good" or "bad" characters could influence the fate of the group. The familial, tribal, ethnic component in food plant evolution was just one, and perhaps a small component of the process. However, we are interested here only in this minor component.

Ethnobotany has a wide range of possible approaches and consequently many possible definitions. According to the adepts of the first modern, North American, approach (HARSHBERGER 1896), ethnobotany studies the plant use and "botanical" knowledge accumulated in primitive, indigenous, aboriginal societies as opposed to "economic botany", i.e., the plant use and related knowledge in advanced agro-industrial societies (ANDERSON 1993, PRANCE 1995, PRANCE et al. 1995, SCHULTES and REIS 1995). The basic problem with this definition resides in the meaning of the words primitive, indigenous and aboriginal, used generally instead of the word tribal. The ethnobotany of tribal societies is in our approach a really important part, but just a part of this science field.

For example, in Central Europe, which is now reintegrating slowly in the European Union, tribal life is no more active. Even without tribes, there is a large indigenous population with a rich but rapidly vanishing traditional knowledge on plants. This knowledge has been explored quite systematically well before ethnobotany was named as a science (DAVIS 1995).

European ethnobotany has a long history rooted deeply in the (mostly lost) tribal traditions, biblical botany and renaissance herbalism (ARBER 1971, SZABÓ 1978, 1979). In the first independent printed book based on conscious and organised ethnobotanical field research – Stirpium Nomenclator Pannonicus, Németújvár, 1583 – all these roots can be clearly identified. The result of this work was a small ethnobotanical book printed as a separate volume (CLUSIUS and BEYTHE 1583), but also annexed to a Pannonian botanical monograph (CLUSIUS 1583, 1584) well before HARSHBERGER defined ethnobotany in 1896. This book belongs to a series of publications written by Hungarian renaissance herbalists of the "Sárvár School" whose members once studied in the homeland of Rudolf Mansfeld, more precisely in the University of Wittenberg (SZABÓ et al. 1992, 2000).

Renaissance herbalism is derived mostly from Greek, Roman, Judeo-Christian (Biblical) and national (folk) traditions. It flourished during the 16th century and may be regarded as a transition between traditional and scientific botany. In herbalism, unwritten ethnobotanical knowledge was merged into organised and printed science. Herbalists recognised gradually the value of natural biological categories ("genera" and "species" in pre-Linnaean sense) creating the base for scientific nomenclature. C. Clusius was especially influential in this respect, using first consequently many "binomials". His books preserved ethnobotanical categories (folk names and knowledge) used in European botany for centuries. Knowledge on classical and renaissance herbalism is still essential in understanding the origin and evolution of plant variability reflected also by different plant names (STIRLING 1995-1998, 1996).

The Linnaean and even the Darwinian period was coined in plant sciences by a general repulsion against unwritten (ethnobotanical) knowledge. Beginning with the middle of the 20th century, however, ethnobotany was increasingly respected as a science and was regarded as an interdisciplinary field focused on the study of orally transmitted botanical information characteristic for different ethnic and/or cultural communities (SZABÓ and PÉNTEK 1976/1996, SCHULTES and REIS 1995, VICKERY 1997, etc.). The collection of plant material and traditional knowledge connected mainly with food plant resources belong also, at least in part, to this approach (VAVILOV 1927/1992, HAMMER 1998, and many further publications from the Gatersleben School, cf. also Mansfeld's World Database of Agricultural and Horticultural Crops: http://mansfeld.ipk-gatersleben.de).

In the second half of the 20th century ethnobotany gained acceptance as the study of relations between plants and people: the study of interactions between local people and their (natural and constructed) environment (PÉNTEK and SZABÓ 1985, MARTIN 1995, BALICK and COX 1996). In this approach, ethnobotany is a part of ethnoecological and/or ethnobiodiversity studies. This new tendency is connected with new phenomena in the history of science: environmentalism and globalisation from one side, and the growing gap between traditional and scientific (organised, computerised, molecular, etc.) knowledge of plants on the other side. The explosive growth of constructed human environment motivated the introduction of a new concept, that of aedobotany for the study of complex man-and-plant interactions around and inside human constructions (SZABÓ 1996b).

European archaeobotanical findings illustrate convincingly that ethnobotany of the Continent (including of course the isles around it) had a major Indo-European integrative background connected with the Neolithic Revolution, the spreading of agriculture and the evolution of Indo-European languages. This integration was coloured of course by many particular tribal traditions. The emergence of organised written (scientific) knowledge in the Roman Empire amalgamated first the Greek, the Roman and the "barbarian" ethnobotanical traditions in a European common knowledge on plants.

The Hebrew ethnobotany (with deep Mesopotamian, Egyptian and Arabic connections) was also very influential in Medieval Christian Europe. The tradition was strong and is still alive (HAYNALD 1879, 1894, LÖW 1888 n.c., 1967, HEPPER 1993, KERESZTY 1998, ZOHARY 1986, ZOHARY and HOPF 1993).

The ethnobotanical integration culminated with Renaissance herbalism merging into European botany also the Asian (Ural-Altaic and Fenno-Ougrian, Hungarian) ethnobotany. The European common knowledge on plants grew further with the elements of Eastern and Southern Asian (Chinese, Indian), Northern, Central and Southern Amer-Indian, African and even Oceanian ethnobotany.

The ancient roots, the medieval influence of Judeo-Christian (Biblical) ethnobotany, the renaissance herbalism (including knowledge on "exotic" and "introduced" plants) modulated the picture up to the quality and quantity registered in modern times .

Introversion is a general characteristic of the European ethnobotany. Ethnobotanists are familiar mostly, if not exclusively with the traditional knowledge of the ethnic group they belong to, and tend to overestimate it for different reasons on the expense of other ethnic groups (BORZA 1968, PÉNTEK and SZABÓ 1985, SZABÓ and RAB 1992, VICKEREY 1997, SZABÓ in BAUER et al. 2001).

Ethnobiodiversity is a complementary concept to agrobiodiversity (HAMMER 1998, GYULAI 2000). It is a new approach, a new way of thinking about man-and-plant interactions by including in the study of interactions the different human cultural (ethnic, language) communities as factors in the evolution and distribution of plants.

The idea emerged in 1990 during a preparatory conference of the environmental Rio-summit (VIDA 1990, SZABÓ 1990). The term was coined later (SZABÓ 1996a, 1997, 1998, 1999).

There are many empirical facts supporting this concept, but the correlation between ethnicity and plant biodiversity is far from clear. Even the correlation between biodiversity (sensu latissimo) and sustainability is subject of controversial scientific discussions (references not cited here).

Conclusions

The ethnobotanical approach is essential in the study of plant-and-man interactions in crop plant (micro)evolution.

- Learning and teaching ethnobotany as an integrative human endeavour may be useful in developing mutual ethnocultural empathy in the new generations.
- The time is still not ripe to integrate ethnobotanical and ethnobiodiversity concepts with emerging theories on general evolution and human ethology.
- Basic concepts of ethnobotany and ethnobiodiversity are still ill-defined.
- Ethnobotanical and ethnobiodiversity studies are important in understanding crop evolution and sustainability.

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Inventorying food plants in France

M. Chauvet [1]

Abstract

The author is currently writing an *Inventory of food plants in France*, covering about 770 species. The book will be illustrated with ca. 1500 original drawings and several hundreds of maps. It includes biological and cultural aspects of plants, their history and uses. The process of writing allowed the author to identify many gaps in knowledge. Compilation of data for so many species also allowed to make interesting comparisons, and opens opportunities for future research. Some preliminary results are presented, highlighting the interest of such inventories in the field of applied botany. Political and ethical outputs are also stressed, at a time when the exchange of genetic resources has become a diplomatic issue.

Introduction

Whoever has been involved in the compilation of an encyclopaedic work knows that it is a lengthy and tedious task, and that it is impossible to anticipate all the problems that arise in the process of searching and formatting information. But we also know as users how valuable such encyclopaedias prove to be on the long term. In this article, I will present the work I have been doing for eight years to produce an *Inventory of food plants in France*. I must ask for indulgence from the reader, who will have to wait one or two years more before checking whether my objectives have been fulfilled. In past centuries, encyclopaedias were issued in many fascicles, allowing readers to get soon aware of their interest. My frustration is that I have to write up to the final chapters including families beginning with the letter Z, before making available the bulk of what is already done.

Presentation of the work

Structure

The book will be arranged by families, in the alphabetical order of their Latin name. Each family begins with an introduction, summarizing its biological features and economic importance. Plants of interest belonging to excluded genera are briefly men-

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tioned when they are excluded from the work because they are out of its scope, or known for uses other than food. The same applies for all the genera included, which are introduced with mention of the excluded species. The main entries deal with species, also arranged in the alphabetical order of their Latin name. This structure will facilitate translations in spite of a complex page setting.

Commercial target

For the publisher (Fernand Nathan, Paris), the intention is to produce a prestige book intended for the great public interested in knowing more about the plants they eat. The book is part of a series of books inventorying the flora and fauna of France, five of them having already been published.

The aim is also to propose it as a reference book for scientists in all the disciplines, not only biological sciences, but also social sciences. Researchers in the fields of history, archaeology, ethnology, cuisine, etc., have limited access to sound scientific information about plants, because it is often too technical and specialized, and not oriented toward their needs.

Scope

Initially, the publisher wanted to include all the plants giving products marketed or collected at a significant level in France. The reader being more a consumer than a farmer, we considered that we had to include plants grown in France as well as imported ones. For imported plant products, we considered those marketed through the general channels (supermarkets, etc.) and those marketed only through ethnic shops.

Traditionally, popular books tend to concentrate on the most visible and valued part of the plant array, i.e. fruits, vegetables and spices. Books on agricultural plants such as cereals or oil crops are very rare, because those plants appear on the market only as processed products. I developed a comprehensive approach, considering as a food plant any species the product of which is consumed (swallowed) for a purpose other than strictly medicinal or psychotropic. A pragmatic criterion for medicinal plants has been the marketing channel. Plants marketed through food supermarkets (such as lime and chamomile teas) have been considered as beverage plants, used for comfort, and included as such. Plants sold through pharmacies only are excluded. Such broad scope allows to retain plants used as colouring agents or additives.

The publisher also agreed to include plants eaten only in one or another of the French tropical *départements*, Guadeloupe, Martinique, Guyane and Réunion. In that case, only the most relevant species are considered, as far as they are part of the local cuisine.

At the end of this enumeration, the conclusion is that quite all the plants marketed in Europe, and most of those marketed in North America, are actually included. With the trend of globalisation, it can be said that most of the plants which are available with commercial standards on the world market are considered. In total, they comprise 770 species, including algae and fungi.

Structure of an entry by species

Heading

The scientific name is followed by common synonyms and the basionym, with author and date of publication. This allows the reader knowing the basic rules of botanical nomenclature to understand why a name is considered as correct, which is always a kind of mystery for most people. When the nomenclatural situation is more complex, a particular paragraph deals with it under “description”.

The number of chromosomes and the genome formula (if relevant) are given.

Popular names are systematically given in French, English, German, Dutch, Spanish, Portuguese and Italian, with details if necessary. In addition, names in the major languages of the area of diversity of the plant may be given here, or mentioned in the text under “history”.

Description

This section presents a short description of the species, with some biological features of interest for the common reader.

Cultivars and cultivar-groups

This section gives a summary of the genetic and morphological diversity within the species. The emphasis is on what can be perceived by the reader. Only the outstanding cultivars are mentioned.

History

This is perhaps the most important and original section. It considers first what is known about the centre of origin, and then follows the diffusion and diversification of the species through space and time. Full attention is given to the history of popular names, and to the social events that influenced the spread of the crop. A selection of landmark historical texts is used through quotations, with plant names in the original language. This allows the reader first to enjoy having direct access to old authors, but more important, to check the context and feel free to reinterpret the meaning. I have always been frustrated with short statements such as “Pliny the Elder mentioned this species”. Too many times, when you go back to the original text, you discover that the identification may be false or biased, and that the author says much more than what is quoted.

The resulting text intertwines aspects of biological and social history, according to the information available.

Ethnology

Here we deal with the role of the plant in mythologies, religion, symbols and cultural life (art, literature, etc.). It is highly variable according to species.

Uses

At the beginning, I thought that writing about uses would be an easy task, because our societies give a great importance to economy. I discovered that only the standard products are quite well documented, and that very few syntheses exist about the diversity of plant products through history and ethnic groups. Ethnologists and historians even lack a common terminology to describe the technologies of food processing. I limited myself to describe, define and classify the different products that may be known to the common reader, or play an important role in nutrition or in history. As usual, I insisted on the popular names of such products and dishes.

Economy

Facts and figures about production and trade worldwide are given. This section being liable to become rapidly obsolete, it is somewhat sketchy, and does not intend to be a market survey.

References

Only the specific references used as sources are mentioned. The general ones will be presented in the introduction.

Additional features

We decided quite naively that each species (and cultivar-group) should come with a line-drawing showing the shape of the plant, and one or several colour drawings showing flowers and leaves, and the organ used, including as it is marketed, and with a cross-section to show its structure and colour. This task has grown into a true adventure, which now allows me to look with another eye at historical illustrations. We had to recruit about ten illustrators, with different skills and backgrounds. Many plant products were simply bought on markets, wherever my travels allowed me to go. For others, we could rely on botanic gardens, genebanks and amateur gardeners. When it was not possible to have access to living plants, we had to draw from photographs. In the process, I discovered how easy it is to retain a misidentified drawing, or a drawing that is not representative of the species. For example, the first drawing of kiwifruit came of course from a good source, the famous historical kiwifruit of the Jardin des Plantes of Paris. However, it proved to suffer from chlorosis, the leaves being unusually yellow; more curiously, it was morphologically hermaphrodite, whereas the kiwifruit is known as dioecious!

A more general finding is that it is easy to find photographs of the organs that are used, but quite impossible to find photographs of flowers of tropical fruits or spices, for example. Nobody seems to worry about the flowers of *Annona* or the fruit of *Syzygium aromaticum*. For Zingiberaceae it is worse. The available photographs of flowers deal mostly with ornamental cultivars, and some popular books don't hesitate in reproducing a photograph of an ornamental *Zingiber* or *Curcuma* to illustrate the spices ginger and turmeric! For Cactaceae, it is the reverse: most books are flower-oriented, and fail to describe the fruit, because writers are mostly amateurs growing Cactaceae as ornamentals. Eventually, the interest of my book will lie in the ca. 1,500 original drawings, and not only in the text, which is a real challenge. As far as possible, a colour map showing the centre of origin and the paths of diffusion of the plant is added. Fortunately, the small size of the maps will compensate the heterogeneity of sources. Adding maps also proved to be a naive idea. After consultation with specialists, I was confirmed in my feeling that even for important plants, it is not possible to draw a map around the Mediterranean, or from Europe to Central Asia. In our era of computers and international programmes, there is a lot of work to do in order to fill those gaps. Finally, a map of France showing the production areas will be added if relevant. This last task was an easy one, as we could rely on the courtesy of the Statistical Department of our Ministry of Agriculture.

Some results

This inventory was initially intended to summarize existing information about market products. Many books exist, and most of them simply repeat what is already known. I progressively discovered that it was not so simple to write such a book, and I constantly need to refrain from trying to solve the contradictions I find by simply gathering information from scattered sources. Gathering systematically this wealth of information allowed me to compare the status of a great many species and to reach some general results I will now present briefly.

Unnoticed changes

We know of many cases in history of one species having been totally replaced by another one for the same use. This includes *Tragopogon porrifolius* replaced by *Scorzonera hispanica* as salsify, and *Brassica nigra* replaced by *Brassica juncea* as a source of French mustard.

Other changes have passed quite unnoticed, possibly because they occur with minor species. For example, pignon nuts are said in all books to come from the Mediterranean species *Pinus pinea*. It is historically true, but now with the high cost of manpower for collecting, only Spain seems to maintain a commercial production of pignons, which obtain a high price. After having had the opportunity to observe the different forms of pignons worldwide, I discovered that most of the product we see in our supermarkets comes from China, and originates from *Pinus koraiensis*. Another source are the Himalayas and Kashmir (marketed by Pakistan) with *Pinus gerardiana*. I assume that both species are considered interchangeable, because I found the Chinese product in an Indian shop, and the Pakistani one in a Chinese supermarket, and both had been imported by the same company.

This “small” observation is quite funny, because our authorities are nervous about “traceability” and wish to impose strict regulations to “novel food”. In this case, we have three different species of *Pinus*, and they do not even belong to the same section of the genus *Pinus*. So, they could perfectly have distinct properties, worth analysing. But who has ever noticed that?

Another example is rocket. In Italy, *Diplotaxis tenuifolia* has partly replaced *Eruca vesicaria* as a salad. They are sometimes distinguished as *ruchetta* vs. *rucola* on the markets of Rome. Botanists can identify them readily even in a salad bowl, because *Diplotaxis* has thicker and bluish leaves, with a narrow terminal lobe, whereas *Eruca* has bright green leaves with a large round terminal lobe. *Diplotaxis tenuifolia* is a well-known wild salad, but it seems that it has been cultivated in Italy only for a couple of decades. As far as I know, no book mentions this fact. One reason for this change may be that *Eruca* leaves wilt rapidly, and have a shorter shelf life than *Diplotaxis*.

The growing market of exotic plant products

Due to the migrations of ‘boat people’ in the 1980’s, Paris now has its Chinatown (13th arrondissement), with big supermarkets and a well-organised importation and distribution system. Chinese companies tend to control most of the French market of exotic and ethnic produce. Paris also has an Indian quarter (near Gare du Nord and passage Brady), an African quarter (near Metro Château Rouge) and scattered Caribbean and Réunion shops, not speaking of less exotic shops from the Mediterranean area.

A similar situation is to be found in most European countries, the ethnic groups concerned varying according to the particular historical links of each country (Pakistanis and Caribbeans for Great-Britain, Indonesians for the Netherlands, Turks for Germany, etc.).

Ethnic markets have been generally ignored by authorities. As long as the products were supposedly sold only to consumers belonging to the relevant ethnic group, the easiest solution was to let them develop. I only noticed that importers have been requested to add a label in French detailing the name and contents of the product. In most cases, the information is faulty, due to the difficulty for translators to find an adequate terminology for ethnic products. One classical example is the so-called ‘arbutus’ or Chinese strawberry, which is the fruit of *Myrica rubra*, and has nothing to do with *Arbutus unedo*.

Ethnic products are now entering the general market, because more and more people enjoy tasting exotic cuisine. Hypermarkets now offer whole lines of exotic products. This creates a strange situation, when we consider the strict regulations that the European Union is supposed to implement about novel food. Recently, an attempt to commercialise the nangaille nut (*Canarium indicum*) from Vanuatu has been stopped due to the lack of toxicological survey. As the producers are small farmers organized in a cooperative, they are simply unable to fund such survey, the nut market being saturated. As there is no significant immigrant community in France from Vanuatu, it is not possible to argue that the nut has been sold on the French or European market for decades, and so it falls under the category of novel food.

Ethnic vegetables grown in France

Another consequence of the development of ethnic markets is that more and more products are grown in Europe. For my book, I gathered some information about those grown in France. My list is surely not exhaustive, but it shows the trend: *Abelmoschus esculentus, Benincasa hispida, Colocasia esculenta* (for petioles), *Dioscorea opposita* (introduced in the 19th century in Sologne!), *Ipomoea aquatica, Manihot esculenta* (for leaves), *Momordica charantia, Ocimum sanctum, Perilla frutescens, Spilanthes oleracea.*

In general terms, two kinds of products may compete with imports (mostly operated by airfreight). Organs such as fruits of *Cucurbitaceae*, which are heavy and costly to transport by air, form the first category. The second one groups leafy vegetables that wilt rapidly, and need a short transport.

A particular case of technology transfer has been the area around Sainte-Livrade (Lot-et-Garonne, South-West of France). At the end of the war in Algeria, a transit camp was created there to host the families of Algerians who had been in the French army. The camp was later occupied by Vietnamese refugees, who hired themselves on the vegetable farms of the area. They could easily convince their bosses to grow Vietnamese vegetables, which were first sold locally and soon in the Paris market.

Wild vegetables

There is a considerable literature about wild food plants in Europe. Unfortunately, it is often limited to lists of taxa with local names and summary indications about uses. We know little about the geographical distribution of their use, their importance in the diet, and their real status. Most of them were possibly only gathered in periods of shortage, or famine. Some were eaten as part of rituals. But how many were really relished and looked after, we don't know.

Anyway, as the traditional rural life is vanishing, the status of wild food is changing rapidly, and merits documenting. Wild vegetables were an important complement to rural diets. Now, they are coming back as a fashion for so-called ‘bobo’ (*bourgeois bohême*) urban people. Some three-star chefs offer them in their menus.

As examples, the wild asparagus, *Asparagus acutifolius*, is still a traditional vegetable in southern France, and is commonly sold in markets. The vineyard leek *Allium polyanthum* is also available, although supplies are becoming rare because vineyards have no longer weeds due to the use of herbicides. Perhaps the most striking change is the fashion for wild salads. A local association in Montpellier every year organizes a field trip to help people identify wild salads in their rosette stage. Only by advertising in newspapers, they bring together about 300 people, which is becoming an important local event.

In Paris, a new market has been created for aspergette, *Ornithogalum pyrenaicum*, which is collected in eastern France (Lorraine) and sold in specialty shops and street markets. In that case, I must confess that the texture of the flower stalks of this plant is mucilaginous, and not worth comparing with a good asparagus.

Plants we eat without knowing

Most books about food plants seem to ignore the changes brought by the industrialisation of food, although this process has begun in the 19th century. I often insist in the conferences I deliver on the fact that we eat many plant products unknowingly, and apparently with no harm. For example, most milk products include guar flour. Very few people know that it is obtained from the seeds of a pulse, *Cyamopsis tetragonoloba*, which is grown for this purpose in the United States, and the young pods of which can be found in Europe in Indian groceries.

Other examples are annatto or rocou, *Bixa orellana*, which is a red colouring agent commonly used in European specialty products (cheeses, sausages, etc.). Fats such as shea butter or karité, *Vitellaria paradoxa*, and illipé (*Shorea* spp.), are now allowed as components of chocolate in the European Union.

Plants generally misidentified

During my research, I also found that some taxa are commonly misidentified. *Raphanus sativus* Daikon Group is now available in European markets. In France, where we have no tradition of eating white big radishes, it is not perceived as a radish. It regularly appears on markets under the name *navet* (turnip), and I had confirmation by a cook (my own son) that it is now currently used by cooks instead of *petits navets*. The reason for that is simple: daikon is always crisp and juicy, whereas turnips are too often fibrous and hollow. Daikon is also easier to peel and cut.

Other examples include *Brassica rapa* Cima di Rapa Group, which is commonly sold in France as a broccoli. I assume that it is a newcomer in France, imported from Italy. Only botanists will notice that true broccoli from *Brassica oleracea* commonly have bluish leaves, and not bright green.

More important is the case of *Cucumis melo* Flexuosus Group, which has constantly been taken as a cucumber. I found it once in a supermarket as Armenian cucumber. But I discovered that the confusion has been constant in history, because this fruit has the shape of a cucumber, is collected immature as a cucumber, and processed and eaten as a cucumber. Only botanists are clever enough to identify it by its distinct ridges. The importance of this cultivar-group of melon is so great in the eastern part of the Mediterranean that I now think that historical data about 'cucumbers' have to be revisited. In the Bible, the 'cucumbers' that the Hebrews remembered having eaten in Egypt were probably this kind of melon.

Lessons and recommendations

The need for applied botany

The examples given above illustrate the interest of mobilizing information in the field of applied botany as a tool of technical and market monitoring, and as a tool of identification for the enforcement of regulations, or their adaptation (e.g., Novel Food Directive). Applied botany is also a necessary basis to implement our commitments towards sustainable development and the rational use of biodiversity. At a time when biology is concentrating more and more on a couple of model species, we need to organize in order to maintain a good level of expertise about the diversity of plants.

In particular, documenting and monitoring the use and market of minor, exotic and wild food plants could best be done through a European network.

The interest of interdisciplinary approach

Integrating information from many disciplines is a nightmare for the writer, but opens fascinating opportunities for research. Compiling information on many species allows a comparative approach of the history of agriculture and human peoples. Since the landmark publication of Alphonse DE CANDOLLE (*Origine des plantes cultivées*, 1883), no synthesis has been published with such a broad scope. There are of course many reasons for that, one being the trend towards specialization in science, and another the gap between biological and social sciences. However, the wealth of data accumulated by the different disciplines allows now to offer new syntheses. The new developments of molecular genetics, by allowing us to overpass the limits of morphological descriptions, open new questions that make necessary to revisit historical, linguistic and archaeological data.

Crops appear as fundamental cultural and historical markers. I was recently asked why DE CANDOLLE's work was still so popular more than a century after its publication. The reason lies there: by bringing crop science into its cultural and historical context, DE CANDOLLE recognized crops as partners of the evolution of our societies. Geneticists now complain that they are often perceived as playing God and creating monsters. Perhaps what the public means by that is that plants are not mere raw biological material, but also an integral part of our cultural heritage. If we want to communicate with consumers and citizens, we have to integrate both approaches.

Political and ethical output

When compiling information on the history of crops, I progressively discovered that most books were incredibly chauvinist. As a European, it was quite easy for me to observe this attitude when reading books written in the United States, which implicitly consider that history really begins with the introduction of the species into United States, whereas for me, these events are quite late avatars in a long sequence, except of course for American crops such as *Phaseolus* beans, maize and pumpkins. The problem is that Europeans usually do the same, starting from only a couple of centuries earlier. Most popular histories of the potato begin with the 'discovery' of the potato by Spanish conquerors, and French writers dedicate half of their texts to the role of Parmentier, who was indeed a great agronomist, but played a limited role in the spread of potato, in spite of the legend that was built later by Republican militants.

Chauvinism is not a particularity of Westerners. Most peoples on earth give themselves an outstanding role in the evolution of crop plants. With the ongoing globalisation and the cultural conflicts we are facing now, reivindications have arisen through the Convention on Biological Diversity and the new Treaty on Plant Genetic Resources. Diplomats from the South argue that crops have been stolen or pirated, and that their countries have to be 'compensated' for that unequal exchange. This atmosphere of mistrust will probably last for a long time.

One thing we can do at least is documenting how the different peoples on earth have domesticated, selected and used plants, and how through millennia of dispersal and evolution, we have now at our disposal such a genetic and cultural diversity. Making available to a broad public such kinds of syntheses may help to show that we are all interdependent, and that we have to behave as good custodians of this common heritage. All the peoples may be proud of their contribution.

The neglected diversity of immigrant gardens in Germany - examples from Bonn

TH. GLADIS [1]

Abstract

In the region of Bonn (Northrhine-Westfalia, West Germany), typical gardens of immigrant families were visited and periodically checked regarding their plant composition and cultivation techniques. As a first step of inventorying these gardens, a preliminary checklist of crop plants is presented and discussed. In addition, the following results were obtained regarding the criteria for establishing a foreign garden culture in Germany:

- Most gardening immigrants originate from farmers' families; they like this work and know seed production techniques very well.
- Arable land is easily available; rents for gardens are low and allow the immigrants to continue their traditional farmers' work.
- Personal preferences to familiar or local varieties let them transfer these seeds or plants to new settling areas.
- Tight neighbourhood to German gardeners and farming immigrants from other nationalities allow exchange of seed and experience.
- Missing opportunities to consume traditional food in Germany lead to the establishment of special markets and restaurants, preferably used by immigrants not originating from farmers' families.

This way, at the level of gardens, Germany developed into a tertiary gene centre for many crops within the past few decades.

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Introduction

Before settled agriculture, people collected, dried and stored fruits and seeds from edible wild plants to survive hard seasons such as winter. Since its very beginning, agriculture contributed to connecting people with the ground they were living from. All circumstances of their life (their living standards, rites, and traditions) changed during the agricultural revolution in prehistory. Permanent use of land resulted in property rights systems and the defence of territories. The houses became more solid, but social differentiation between self-sustaining families within the society was low. There was no specialisation at that time. Later on, impoverished and landless people went to places where chances to work arose, comparable to seasonal workers as we know them nowadays.

During the ongoing differentiation processes, farmers always tried to remain on their land but unlimited expansion was not possible, so some children of farmers had to migrate or take on other professions. Many social conflicts could not be solved peacefully, so people had to leave, and after new periods of migration they started to settle in other places again.

People took seeds and plants with them as victuals and gifts or to trade and exchange material. We can reconstruct the migration routes of people as well as the routes of their preferred animals and plants. Cultivated plants and domestic animals are part of the inalienable goods of human cultural heritage. Among other cultural goods, seeds and animals were captured by the conquistadors during wars. Farmers became slaves, loosing their freedom, families and social networks. After contact with the Americas, many cultivated plants entered the Old World, such as corn (*Zea mays* L.), garden bean (*Phaseolus vulgaris* L.), potato, pumpkin, squash, tomato, and tobacco. Alfalfa, barley, cabbage, wheat, and others went together with European emigrants and African slaves in the opposite direction. Even animals and wild plants were transferred, some intentionally, others unintentionally. Some escaped from culture and established themselves very well in new growing localities in Europe, e.g., the neophytic species *Robinia pseudoacacia* L., *Senecio inaequidens* DC., and *Solidago canadensis* L.

Past and present migrations

When the Romans occupied southern German territories along the Rhine River, they tried to establish their own system to subdue the local population and to integrate it later on step-by-step. This process is called Romanisation. The Romans brought their language and culture to the north, including such new crops as spelt, bread wheat, grape, fruits, and fodder legumes. The Germans kept animals only and had just started to develop agriculture (SEIDL 1995). During the occupation period, Roman soldiers founded families here, on the other side of the Alps, and not all German slaves returned to the North after being released. Both sides adopted and integrated elements and crops of the foreign culture into their own cultural system. The same process is happening thousands of years later: the Italian preferences for special vegetables of American origin are well known, as the examples of peppers, tomatoes and zucchini illustrate. Italian restaurants exist in all parts of the world now.

After World War II, the reestablishment of the economy of the destroyed and divided Germany was achieved with the help of guest-workers from many different countries. Germany planned to host them for a couple of years - as long as their own population was too low. Many of these guest-workers preferred to stay in Germany afterwards, for a longer period or permanently. They took their families, wives and children with them and feel at home here now. They go back to their home countries as visitors and guests during vacation and holidays, some of them several times per year. Religion and culture are also influenced this way. The communication between the German population and the immigrants increases from generation to generation, and many children speak their mother tongue as well as German fluently. At the very beginning, the German market did not provide special food, clothing, etc. for the cultural demands of the immigrants. Thus, they started to produce these things themselves as far as possible or to get them via exchange with family members remaining in the respective country of origin.

However, immigrant groups started to provide these things for themselves very soon, and there are more and more Germans now accepting the broader and more colourful products offered by immigrant traders. There are many different regions of the world and many nationalities represented in the city of Bonn, for instance. Eastern and western European immigrants dominate, followed by those from western and southern Asia and northern Africa. Persons from the Americas and Africa were not the focus of the present studies. Many people come e.g. from Turkey, Palestine, Morocco, Italy, Romania and from the former Soviet Union.

Garden and plant uses

In the example of the southern border of the former German capital of Bonn, gardens of immigrant families were visited to talk with the people and were checked focussing on typical and especially rare and less-known cultivated plants (GLADIS 1999). The cultural differences between German and foreign people in neighbourhoods are obvious. Within the town, representative and ornamental gardens dominate but at the border, where more immigrant families live, more and more gardens are used to produce vegetables, fruits, spices, and as a place to relax and spend leisure time. Many of the immigrant families, some of whom originate from countries in the centres of genetic diversity for particular crops, described by VAVILOV (1926), prefer to spend as much time as possible in these gardens. They live in self-made cabins, grow their crops, cook tea, prepare and consume their food, invite friends, neighbours and the whole extended family several times per year.

The hedges are tight, the fences full with climbing beans, peas, pumpkins. Water is a limiting factor in the gardens. Rainwater is collected and sparsely applied to the crops. It is relatively easy to distinguish between common plant varieties and seeds which the immigrants brought along with them. The local varieties of immigrants are not homogeneous. Each family has material with morphologically distinct characters for different uses. Seed growing is commonly observed.

In some cases the gardeners cultivate plant species which are not yet reported as crop plants for the territory of Germany officially. Two examples of such plants are *Chaerophyllum byzantinum* Boiss. and *Trachystemon orientalis* (L.) G. Don. In Turkey, both are wild plants collected by the people in their native environment. *Chaerophyllum* has a flavour comparable to parsley and is frequently used as a spice throughout the year. *Trachystemon* is harvested in early spring. The leaf stalks are consumed as vegetable. Both plant species are not available from the German flora. The preferences for these plants led to the decision to transfer them and to cultivate them here for use in kitchen. *Trachystemon orientalis* is a beautiful slow growing plant. It is offered in garden markets sometimes as an ornamental for shaded places in gardens because of its nice blue flowers and the dark green foliage.

A preliminary checklist of the plants observed in immigrant gardens and the respective nationalities of the gardeners are presented in Table 1.

Tab. 1: List of cultivated plants observed in immigrant gardens in southern parts of Bonn (excluding weeds and grassland)

Plant names	uses[2]	Frequency	differential species, remarks
Abelmoschus esculentus (L.) Moench	v	3	E*
Achillea sp.	o	3	vegetatively, no flowers observed
Alcea rosea L.	o	3	
Allium cepa L.	v	1	S*
Allium cf. *porrum* L.	v	1	S* comparable to pearl onion
Allium fistulosum L.	vs	3	
Allium sativum L.	s	2	S*
Allium schoenoprasum L.	s	3	
Allium × proliferum (Moench) Schrad. ex Willd.	vo	3	

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[2] see legend

Tab. 1: continued

Plant names	uses	frequency	differential species, remarks
Amaranthus caudatus L.	o	2	
Anethum graveolens L.	s	2	
Antirrhinum majus L.	o	1	
Apium graveolens L. var. *rapaceum* (Mill.) Gaud.	v	2	
Armoracia rusticana Gaertn., Mey. and Scherb.	s	3	used ?
Asparagus officinalis L.	o	3	used ?
Aster sp.	o	1	autumnal flowers
Atriplex hortensis L.	vo	2	S* only green varieties
Bergenia hybrids	o	3	
Beta vulgaris L. convar*. cicla* (L.) Alef.	v	2	S*
Beta vulgaris L*. convar. vulgaris*	v	1	S*
Brassica oleracea L. var. *capitata* L. s.l.	v	1	red cabbage
Brassica oleracea L. var. *gemmifera* DC.	v	3	S*
Brassica oleracea L. var. *gongylodes* L.	v	2	
Brassica oleracea L. var. *italica* Plenck	v	3	??
Brassica oleracea L. var. *medullosa* Thell.	v	3	??
Brassica oleracea L. var. *sabauda* L.	v	3	S*
Brassica oleracea L. var. *viridis* L.	v	1	S* “black kale” (T)
Brassica rapa L. em. Metzg.	v	3	S* inflorescences used (T)
Brassica rapa L. em. Metzg. ssp. *rapa*	v	3	S*
Bryonia dioica Jacq.	t	2	with espalier
Calendula officinalis L.	o	1	
Callistephus chinensis (L.) Nees	o	2	
Calluna vulgaris (L.) Hull	o	3	modern varieties
Calystegia sepium (L.) R. Br.	ot	2	
Capsicum annuum L.	vs	1	S* hot and vegetable peppers
Carthamus tinctorius L.	s	3	
Castanea sativa Mill.	f	3	
Centaurea cyanus L.	o	3	
Chaerophyllum byzantinum Boiss.	s	3	fresh consumed (T)
Chrysanthemum leucanthemum L.	o	3	
Chrysanthemum parthenium (L.) Bernh.	o	3	
Chrysanthemum-Indicum hybrids	o	1	perennials
Cicer arietinum L.	v	3	unripe roasted (L, P)
Cichorium endivia L. var. *latifolium* Lam.	v	2	
Clematis vitalba L.	t	2	
Convolvulus arvensis L.	t	2	
Coreopsis sp.	o	3	

Tab. 1: continued

Plant names	uses	frequency	differential species, remarks
Coriandrum sativum L.	vs	2	S* (M)
Cosmus bipinnatus Cav.	o	2	
Cucumis melo L.	f	3	
Cucumis sativus L.	v	2	S* outdoor and in greenhouses
Cucurbita maxima Duch.	v	1	S*
Cucurbita pepo L.	v	1	S*
Cynara scolymus L.	vo	3	
Dahlia hybrids	o	2	
Daucus carota L.	v	2	few also violet coloured
Dianthus barbatus L.	o	3	
Dianthus caryophyllus L.	o	3	
Digitalis lanata Ehrh.	o	3	
Digitalis purpurea L.	o	3	
Doronicum sp.	o	3	
Eriobotrya japonica (Thunb.) Lindl.	fo	3	young plants, sometimes potted (T)
Eruca sativa Mill.	s	1	S*
Erysimum cheiri (L.) Crantz	o	2	
Euphorbia lathyrus L.	t	3	
Foeniculum vulgare L. var. azoricum (Mill.) Thell.	v	3	
Forsythia sp.	ot	3	
Fragaria ×ananassa Duch.	f	2	
Fraxinus excelsior L.	t	3	large branches removed
Geranium sanguineum L.	o	3	
Gladiolus hybrids	o	2	
Hedera helix L.	ot	2	
Helianthus annuus L.	fo	1	
Helianthus tuberosus L.	s	2	
Heuchera hybrids	o	3	
Hosta hybrids	o	3	
Impatiens glandulifera Royle	o	3	
Iris germanica L.	o	1	
Juglans regia L.	f	2	
Lactuca sativa L. var. *capitata* L.	v	1	also ice salads
Lactuca sativa L. var. *crispa* L.	v	3	S*
Lactuca sativa L. var. *longifolia* Lam.	v	2	S*
Lagenaria siceraria (Mol.) Standl.	v	3	S*
Lathyrus latifolius L.	o	3	
Lathyrus odoratus L.	o	3	
Lens culinaris Medik.	v	3	(T)

Tab. 1: continued

Plant names	uses	frequency	differential species, remarks
Lepidium sativum L.	s	2	S*
Levisticum officinale W.D.J. Koch	s	3	
Ligustrum vulgare L.	t	3	
Lupinus-polyphyllus hybrids	o	2	
Lycopersicon esculentum Mill.	vf	1	S* only varieties with red fruits
Malope trifida Cav.	o	2	
Malus domestica Borkh.	f	2	
Manihot esculenta Crantz	s	3	E* (Ph)
Mentha rotundifolia (L.) Huds.	sot	3	soil cover (L, M)
Mentha ×piperita L.	sot	2	soil cover (L, M)
Momordica charantia L.	vs	2	S* (Ph)
Ocimum basilicum L.	s	3	
Origanum vulgare L.	s	3	used ?
Paeonia sp.	o	2	Herbs
Papaver somniferum L.	so	2	S* often with opening capsules
Petroselinum crispum (Mill.) Nym. ex Hill. *var. vulgare* (Nois.) Dan.	s	1	S* mainly simple foliage
Phaseolus coccineus L.	vo	3	S* young pods and dry seeds
Phaseolus vulgaris L. *var. nanus* (Jusl.) Aschers.	v	2	S* young pods
Phaseolus vulgaris L. var. *vulgaris*	v	1	S* young pods and dry seeds
Phlomis sp.	o	3	
Phlox paniculata L.	o	3	
Picea abies (L.) Karst.	t	3	large branches removed
Pinus sylvestris L.	t	3	large branches removed
Pisum sativum L. s.l.	v	2	S*
Populus sp.	t	3	young plants
Primula vulgaris Huds.	o	2	
Prunus avium (L.) L.	f	3	
Prunus cerasus L.	f	3	
Prunus domestica L.	f	2	
Prunus persica (L.) Batsch	f	2	
Prunus laurocerasus L.	o	2	
Pyrus communis L.	f	3	
Quercus robur L.	t	3	large branches removed
Raphanus sativus L.	v	2	S*
Rheum rhabarbarum L.	v	2	
Rhododendron sp.	ot	3	
Ribes nigrum L.	f	3	
Ribes rubrum L.	f	2	
Rosa sp.	ot	2	modern garden roses

Tab. 1: continued

Plant names	**uses**	**frequency**	**differential species, remarks**
Rubus laciniatus Willd.	ft	3	
Rubus idaeus L.	f	2	
Rubus sp.	tf	2	
Rumex patientia L.	v	3	
Salvia officinalis L.	s	3	
Salvia viridis L.	o	3	
Sedum acre L.	o	3	
Sedum cf. *spurium* M.Bieb.	o	1	
Sedum telephium L.	o	1	
Sempervivum tectorum L.	o	1	
Solanum melongena L.	v	2	S*
Solanum tuberosum L.	c	2	
Spinacia oleracea L.	v	2	S*
Syringa vulgaris L.	ot	2	
Tagetes erecta L.	o	2	
Tagetes patula L.	o	2	
Thuja occidentalis L.	ot	2	
Thymus vulgaris L.	s	2	
Trachystemon orientalis (L.) G. Don	v	3	(T)
Trigonella foenum-graecum L.	vs	3	S* (P)
Triticum aestivum L. em. Fiori and Paoletti	c	3	
Tropaeolum majus L.	os	3	
Vicia faba L. ssp. *faba*	v	2	
Vigna unguiculata (L.) Walp.	v	3	E* (E)
Viola odorata L.	o	2	
Viola × *wittrockiana* Gams	o	2	
Vitis sp.	f	2	
Vitis vinifera L.	f	2	
Zea mays L.	c	1	S*

Legend

c = cereals, starch pl.	f = fruit	1 = regular	E* = experimental cultivation
o = ornamentals	s = spices, medicinal pl.	2 = frequent	S* = seed growing observed
t = technical/tolerated	v = vegetables	3 = rare	?? = ownership not clear

Nationalities: Egypt (E), Italy, Lebanon (L), Libya, Moldavia, Morocco (M), Palestine (P), Philippines (Ph), Romania, Turkey (T)

Gardening techniques and plant preferences

Some of the home garden areas are used jointly by several families. There are no hedges nor fences to separate these gardens sometimes. Paths between the “beds” do not exist. Each square metre is used to grow something. If there is space outside the own garden, people enlarge their cultivated territory by planting less valuable crops which are needed in larger quantities in front of them: beets, corn with beans, peas, kale, pumpkins. To get the maximum yield from as many plant species as possible, the gardeners apply a system of intercropping and crop rotation throughout the year. There is scarcely ever open soil except some weeks during winter time. Depending on the size and position of the gardens, the people dig manually or plough with larger machines. As early as possible, broad beans (*Vicia faba* L.) are sown, and between the rows other crops are later sown, e.g. potatoes. Squash and pumpkin cover the same ground at the end of the growing season. This enables the people to have up to three harvests per year from one piece of land. Yellow-eared corn land races (*Zea mays* L.) are frequently grown together with climbing and runner beans, cucumbers, and pepper (*Capsicum* spp.), beet, leek, kale and lettuce (for harvesting of seed). If the plants do not get enough light, the corn plants are partially defoliated. The sowing is not usually done in regular lines or rows, but more frequently in lots. Tender species are initially covered with refuse plant material, in addition to old parts of clothing or spreads during cold and rainy days. Sowing these crops indoors or in self-made greenhouses, such as German gardeners do, is less popular but necessary for tomatoes (against *Phytophthora*-infestations), melons and eggplants *(Solanum melongena* L.). In some years, the eggplants do not grow well outdoors because of climatic factors. The gardeners continue growing and selecting early ripening types thus, trying to adapt the crops to the new environmental conditions.

The intraspecific diversity is extremely high in garden beans. It seems to be the most important vegetable species found in immigrant gardens. They have two common uses: the young fruits are consumed as vegetables, and the ripe seeds are used as a widespread protein source. Many special landraces exist in Bonn originating from different cultures and countries. These landraces are exchanged between gardeners, then individually selected and carefully propagated. Bushy types are rarely found, because they are thought to be less tasty and lower in yield. In some cases even the runner bean (*Phaseolus coccineus* L.) is used as dry bean, but only rarely and in small quantities besides in a garden of a woman from the Philippines. She prefers to use the young pods of this species and grows it as a long flowering ornamental and as a permanent yielding vegetable at the same time.

For seed growing of bi- and perennial crops, the selected individual plants flower for several years. The selected plant remains and bears seed as long as it lives. A typical example for this technique is the so-called black kale (*Brassica oleracea* L.

var. *viridis* L.). The large blue-green or reddish leaves are used to prepare special leaf rolls, stuffed with a mixture of minced meat, rice, onion, garlic, hot pepper and further spices.

From poppy (*Papaver somniferum* L.), unfilled pink- or violet-flowering landraces with spontaneously opening capsules were cultivated until 1999. At the moment, the ornamental, filled red-flowering peony poppies from seed markets are preferred. From this variety even the seeds are used as condiment or to prepare sweets.

Mint species are covering large areas in some gardens. They are frequently used crops, they cover the soil and supply a fresh aroma during hot and dry seasons. Leafy types of coriander are grown in large quantities by some immigrants too. This species is used as condiment and as vegetable e.g. by people originating from Morocco. The plants are grown periodically through the whole year and harvested with a scythe sometimes when starting to flower.

Intensive soil treatment (e.g. watering) and daily picking in the garden is mainly performed by females. The water supply to the soil is regulated by these treatments along with the fact that the soil is often completely covered with plants. In dry years, the soil is protected from becoming encrusted and cracking. In extremely wet seasons, the crops are surrounded by shallow moats. The water can flow slowly away without eroding the soil, and through frequent picking, fresh air is provided to the roots. They do not rot and the plants can grow well.

Some of the plants are grown in monocultures, e.g. chickpea, coriander, mints, parsley. Some grow in rows (cucumber, egg plant, fenugreek), where others are sown or planted to fill gaps (garden orache, *Atriplex hortensis* L.). Some plants surround the cabins (ornamentals, some frequently used spices) or are grown alone (artichoke, manioc). The harvest follows the cycle of fast-growing neighbour plants like pumpkins; other rules are to cut as little as possible if these plants or plant parts are not used at the moment but would bear edible leaf or fruit. Chemical plant protection and manure is scarcely applied. Some of the immigrants use compost or dried and pulverised plant material instead of mineral fertilisers.

It is not possible to define general rules for immigrant gardens because the gardeners come from different nations and often have very distinct personal preferences. The most important component are the plants, followed by fences or hedges and cabins. Immigrant gardens contain only small cabins or self made arbours of simple construction. The owners have not much money to spend it for exclusive buildings and fences. These gardens look like permanent interim arrangements, easy and fast to establish at other places if necessary. Most of the gardeners have one or sometimes several garden areas to provide their families with fruits, vegetables and spices year-round. Self-sufficiency is their main aim, and some even keep animals like chicken and sheep there. Because the people spend nearby more time there than in their flats, these immigrant gardens should not be named and classified as home gardens but as a separate, independent category of gardens, comparable with the Cuban 'conucos' (see HAMMER et al. 1992-1994) or the 'road gardens' described by ARROWSMITH et al. (1998) from rural regions of lower Austria.

Interactions and frequent travelling activities of people from different regions promote their integration into the German society. Families manage their own gardens in order to have enough traditional food, making them independent from the market. The more that immigrants live and work in an area, the more arable land is used for gardens. The rents for leasing are very low - in contrast to the price of soil. Limitations to gardening do not exist other than the time and energy of the people.

The immigrants contribute actively to increase the diversity of cultivated plants in Germany by farming, gardening, trading and exchanging their native germplasm. They influence the markets through selecting of species and varieties (see HAMMER et al. 2001). People from Asia and Russia often establish special shops with exotic food and spices, or species which were used by Germans in former times and which are neglected crops here today (e.g., buckwheat, *Fagopyrum* spp.; cranberries, *Vaccinium* spp.). These exotic or forgotten foods reach more and more reputation for German consumers as well.

Gene centres

Germany is not told to be part of a centre of crop biodiversity. It is known as a typical non-centre (HARLAN 1971). At the moment, ten **primary** gene centres are defined and accepted by scientists as bio-geographic regions where wild relatives occur together with a very high intraspecific variation of cultivated plants. Migration processes led to a semiconservative distribution of cultures and crops (SZABÓ 1996), not affecting the diversity of the centres of origin. Besides these primary gene centres, centres of biodiversity or primary hot spots of crop diversity **secondary** centres exist. They are characterised by the non-origin of the respective crop. Secondary centres are frequently geographically isolated. Wild relatives of the respective crop are missing (SCHMALZ 1980). The evolutionary processes and domestication of species introduced from other regions of the world continue but selection pressure differs and new characters are evolving in new natural and cultural regions soon, frequently with old farming tradition. In these cases, only the plant material is transferred while the primary farmers and their culture remain. Examples for a primary gene centre on species level is America for garden beans. The genus *Phaseolus* has about 50 wild species, five of which have been domesticated from still living wild forms of central America (DEBOUCK 2000). Western Asia and the Mediterranean area are examples for secondary centres of this plant species. A third case may be observed, when emigrants transfer seed and plant to another eco-geographic environment. Farmers and their seed move together and found **tertiary** gene centres for those crops they took with them there. The Afro-American culture is such an example. Typical crops from Africa were introduced together with the slaves. These African slaves, originating from different regions of their continent continue to grow and select their plants. They have lost their local identity, try to adapt themselves as well as their plants to the new climatic and cultural conditions. They start to grow and to exchange material, to select another way as the previous generations in Africa did. With respect to these findings, Germany may be defined as a very young tertiary gene centre for many garden plants now.

From scientific point of view, crop plant research has neglected the diversity of multicultural immigrant gardens in Germany up to now. Transfer, propagation, private plant and seed exchange over cultural borders – they essentially depend from migration and widen the bottle neck for crop diversity caused by plant breeding. This informal management of plant genetic resources is one of the few sources of new material in countries like Germany besides plant breeding and material transfer from gene banks and Botanical gardens. Within their private gardens, the immigrants test from case to case common seed and compare these plants with their traditional varieties and those received from their neighbours. It is a good example for a flexible on-farm management on a small scale. Crop evolution is ongoing, plants are selected and adapted the same way as it has been done by farmers all over the world for thousands of years. The experience collected with genetic erosion during the last century and the loss of diversity of cultivated plants in the industrialised countries should teach us to monitor these processes carefully without influencing them to reduce the risks for a maximum foreseeable loss. This will request a change of our behaviour to less restrictions and prejudices, to more tolerance and interest in different cultures.

Acknowledgement

I want to express my gratitude to all the visited immigrants. They were open for discussion about their gardens, plants and personal situation. They explained their techniques very patiently, the personal preferences for plants and spent their time uncomplainingly to declare these “trivial things” to me. Dr. Klaus Pistrick from IPK Gatersleben, Dept. of Taxonomy, supported me through the determination of wild plants originating from Turkey.

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Unconscious selection in plants under domestication

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Abstract

Two forms of selection operate (and complement each other) in plants under domestication:

- Selection consciously applied by the growers for traits of interest to them.
- Unconscious selection brought about by the fact that the plants concerned were transported from their original wild environments into new and usually very different human-made environments. Numerous adaptations vital for survival under the wild conditions lost their fitness under the new sets of conditions. New traits were *automatically* selected for, leading to the build-up of “domestication syndromes”, each fitting the specific agricultural system provided by the grower.

In this paper, the evolutionary consequences of the introduction of plants into several anthropogenic sets of conditions are evaluated. These include: (a) The choice between seed planting and vegetative propagation. (b) The choice between growing plants for their seeds, for their fruits, or for their vegetative parts. (c) Introduction into the system of tilling, sowing, reaping and threshing.

Introduction

Two types of selection operate (and complement each other) in plants and animals under domestication:

- There is the selection applied consciously by the growers or by the herders (selective breeding) for traits of interest to them.
- There is unconscious selection brought about by the fact that the plants or animals concerned were transported from their original wild habitats, and placed in new (and quite different) human-made environments. The shift in the ecology led automatically to drastic changes in selection pressures. In response to the intro-

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> duction of the plants and/or animals into the anthropogenic environment, numerous adaptations vital to survival in the wild lost their fitness and broke down. New traits were *automatically* selected for, resulting in the build-up of characteristic "domestication syndromes" - each fitting the specific agricultural, horticultural or husbandry system provided by the domesticator.

The role of unconscious selection in the evolution of crop plants has been evaluated by several authors (DARLINGTON 1963, 1973, ZOHARY 1969, 1984, HARLAN et al. 1973, HAMMER 1984, HANELT 1986, HEISER 1988, ZOHARY and HOPF 2000). It is now widely accepted that this type of selection shaped many of the traits that characterise plants under domestication, and distinguished them from their wild relatives. Indeed this approach has already considerably assisted crop-plant evolutionists in their reconstruction of the evolution of grain crops, vegetables, fruit trees, and tubers and corms. This paper aims at an updated outline of this process. It traces some of the main ecological shifts introduced by the transfer of plants into cultivation. It sketches the evolutionary consequences that could have been brought about, in response to these environmental changes.

Maintenance practices and their impact

Two principal modes of crop maintenance have been traditionally employed for handling plants under cultivation. In the bulk of the grain crops, in numerous vegetables and truck crops, and in some ornamentals, the grower continues to maintain his plants by **seed planting**, i.e., in the same way their progenitors reproduce in the wild. In contrast, in most fruit trees and corm and tuber crops, in numerous ornamentals, and in some vegetables, domestication depends on a shift from reproduction by seeds (in the wild) to **vegetative propagation** (under cultivation). The choice between seed planting and vegetative propagation *automatically* sets into motion two very different courses of evolution in plants under domestication:

With very few exceptions (such as nucellar seeds in several *Citrus* crops and in mango) seed planting means sexual reproduction. In other words, seed planted crops undergo a recombination-and-selection cycle every sowing. Consequently such crops have had, under traditional farming, hundreds (or even thousands) generations of selection. They were repeatedly moulded into

(i) clusters of inbred lines (in predominantly self-pollinated crops), or

(ii) distinct cultivated races (in cross-pollinated crops).

In numerous sexually reproducing crops, the results of such repeated cycles of selection are indeed impressive. Under domestication, these crops diverged considerably from their wild progenitors; and the cultivars are distinguished from their wild progenitors by complex syndromes of both morphological and physiological traits. Numerous adaptations vital to survival under wild conditions broke down under cultivation; and many domestic ones have evolved.

In comparison, vegetatively propagated crops have had an entirely different history of selection. "Cultivars" in these crops are not true races but just clonal replications of very rare "exceptional individuals" with superior fruit or tuber qualities that are - as a rule - highly heterozygous. They were originally picked up by the cultivator from variable, panmictic, wild populations; and later also from among segregating progeny of spontaneous and/or man-made crosses between *cultivated* × *cultivated* clones, or *cultivated* × *wild* individuals. In the hands of the grower, vegetable propagation has been a powerful device to evade genetic segregation, and to “fix” desired types. By discarding sexual reproduction and inventing clonal propagation the farmer was able to (i) select rare individuals with desired traits from among a large numbers of variable, inferior plants, and (ii) duplicate (clone) such superior types to obtain a steady supply of genetically identical saplings. In the case of fruit trees and corm and tuber crops, this is no small achievement. Because these vegetatively propagated crops are mostly cross-pollinated and widely heterozygous, most individuals obtained from planting seeds of attractive parents (even progeny derived from commercial cultivars used today) are economically worthless. Thus, the change from seed planting to vegetative propagation has been the practical solution to assure a dependable supply of desired genotypes. As stressed by ZOHARY and SPIEGEL-ROY (1975), in most fruit trees this invention made cultivation possible. This is apparently true also in numerous corms and tuber crops.

In terms of selection, domestication of vegetatively propagated crops is largely a single step operation. With the exception of somatic mutations, selection is completed the moment the clone is picked up. In traditional agriculture, the turnover of clones was apparently slow, particularly in the perennial fruit trees. Appreciated genotypes were maintained for long periods of time. Thus, in sharp contrast to sexually reproducing cultivated plants, vegetatively propagated crops underwent (under domestication) only few recombination-and-selection cycles. Consequently, as far as basic adaptations they remained closer to their wild progenitors. Thus, wheat or pea (which originally were adapted to Mediterranean climatic conditions) evolved cultivars fitting a wide range of climatic regimes – from Scandinavia to Ethiopia. In contrast, cultivated apple still needs winter chilling, the date palm is able to fruit only in hot and very dry environments, and the cultivated olive remained a characteristic Mediterranean plant, not very different from its wild ancestor. In fact, so strict are the climatic requirements of the olive that climatologists use it as a reliable indicator for Mediterranean conditions.

Pollen and seed fertility (including chromosome stability in meiosis) are additional traits in which one finds wide differences between seed planted crops and their vegetatively propagated counterparts. Sexually reproducing plants are automatically selected, each generation, for their fertility. Under such a reproductive system, mutations and/or chromosomal changes affecting fertility will be promptly weeded out. In other words, in seed planted crops, stabilising selection maintains fertility. As a rule, cultivars will be fully pollen fertile and seed fertile. In addition, their chromosomes will pair normally in meiosis. In contrast, shifting to vegetative propagation brings about drastic relaxation of the stabilising selection that under sexual reproduction keeps fertility rigorously intact. Under vegetative propagation, sterile genotypes will be able to maintain themselves as clones. Under such conditions, one would expect to find numerous cases of semi-sterile and sterile cultivars, as well as intra-crop chromosomal polymorphism such as several ploidy levels, including triploids, pentaploids, aneuploidy and other meiotically unbalanced chromosomal situations.

The choice of the plant's part

Different crops are grown for different parts of the plant's body. Some cultivated plants are raised for their *vegetative parts* (roots, corms, leaves, stems, etc.). In others, the *reproductive parts* (flowers, fruits, seeds) constitute the agricultural products. In addition, the choice of the part (or parts) used, leads automatically to the operation of contrasting selection pressures, particularly in traits concerned with the reproductive biology of the crops.

As already noted, when crops are grown *for their seed* (or at least when crops are seed planted) they stay under constant stabilising selection that safeguards their seed fertility. Grain crops have the most rigid protection of this kind. The evolutionary fitness in these plants depends decisively on normal development of their flowers and fruits, on full fertility, and on normal chromosome pairing in meiosis. Deviants are promptly weeded out, and the reproductive system is kept in balance. It is no wonder that among cultivated plants, grain crops are the most conservative in this regard. They are, as a rule, fully fertile. They are also characterised by balanced chromosome systems, and they show very little chromosome divergence under domestication. With few exceptions (such as addition hexaploidy in bread wheat), the chromosome sets in grain crops are *identical* to those found in their wild progenitors. In seed planted vegetables grown for their vegetative parts, flowers or fruits, stabilising selection to maintain pollen and seed fertility might be somewhat laxer; yet the very maintenance by planting of seeds keeps fertility in these crops intact.

Considerable reduction in pollen and seed fertility (as well as in chromosome stability) is tolerated in *vegetatively propagated* crops *grown for their fruits*. In this group (the bulk of the fruit crops) the production of fleshy, tasty fruits is at premium; but not the production of seeds. In fact, growers frequently prefer (and consciously select) clones with seed-less fruits, or with reduced number of seeds in the fruits. Several solutions how to curtail or prevent seed set without harming fruit development evolved in horticulture. Under traditional horticulture, conscious preference for seedless types leads rather frequently to establishment of mutations conferring drastic decrease in seed set, or rare seed set due to triploidy (e.g., in some pear cultivars), as well as the incorporation of mutations inducing parthenocarpy (e.g., in bananas or non-Smyrna-type cultivars of fig).

Crops *maintained by vegetative propagation* and *grown for their vegetative parts* exhibit the most drastic disruption of their reproductive systems; and the most bizarre chromosomal situations among cultivated plants. Because of their mode of propagation, the pressures exerted on such crops to increase vegetative output are rarely counterbalanced by normalising selection to retain sexual reproductive ability. Tropical root and tuber crops provide us with good examples for this mode of evolution. Cultivated clones of cassava, yams, sweet potato and taro often show drastic irregularities in flowering. In some cultivars flowering ceases altogether, or almost altogether. When flowers do appear they are frequently semi-sterile or sterile. Also chromosomally, some of these crops are exceptionally polymorphic, and contain clones showing different levels of polyploidy; including 3x, 5x or even higher meiotically unbalanced chromosome complements. Thus in the yams *Dioscorea alata* is known to contain 2x, 3x, 4x, 5x, 6x, 7x and 8x clones; and *D. esculenta* 3x, 4x, 6x, 9x and 10x clones (HAHN 1995). Sugarcanes confront us with even more complex chromosome variation. Cultivated clones in this crop are all highly polyploid and frequently aneuploid. Their chromosome numbers range from 2n = 80 to 2n = 125 (ROACH 1995). Another feature of sugarcanes (as well as of several other vegetatively propagated crops grown for their vegetative parts) is the rather common origin of cultivars by distant inter-specific hybridisation. Since they do not have to pass through the sieve of sexual reproduction, such largely sterile and/or chromosomally unbalanced hybrids are effectively maintained in cultivation.

The impact of sowing and reaping

Traditional grain agriculture depends on the practice of *sowing* the crop in the tilled field, *reaping* the reproductive parts soon after seed maturation, and *threshing out* the grains. Sowing and reaping automatically initiate selection towards the following changes in plants grown for their grains, setting them apart from their wild progenitors.

Loss of the wild-type seed dispersal devices: This is perhaps the most conspicuous difference that separates grain crops from their wild relatives. It is also one of the most intensively studied changes under domestication (DARLINGTON 1963, ZOHARY 1969, HARLAN et al. 1973, HEISER 1988, HILLMAN and DAVIES 1990). Seed dispersal is a most vital adaptation in plants under wild conditions; and in each wild progenitor, effective devices have evolved to ensure this function. Under the system of sowing and reaping, the grower collects and casts the seeds. Consequently, the wild-type seed dispersal apparatus looses its function, and unconscious selection leads to retention of the seeds on the mother plants. Most obvious is the shift from shattering spikes or panicles (in wild cereals) to the non-shattering condition (in their cultivated counterparts), and the parallel development of non-dehiscent pods in domestic pulses. In most grain crops tested (e.g., wheats, barley, lentil, pea), the shift to non-shattering or non-dehiscence is being controlled by a single principal mutation, or by two such mutations.

Even and rapid seed germination: A second major outcome of introducing the wild grain plants into the regime of sowing and reaping is the loss of the wild-type seed germination regulation (HARLAN et al.1973, HEISER 1988, ZOHARY and HOPF 2000, pp.18, 93). Under cultivation, there is a premium on even, rapid germination; and the wild adaptation of seed dormancy breaks down.

Other traits of grain crops that could have been moulded by unconscious selection: Several other traits seem to have been automatically selected for, once grain plants have been introduced into agriculture (HARLAN et al. 1973, HEISER 1988).

These include:

- A shift towards more erect habit, synchronous tiller production, and uniform seed ripening.
- Increase of seed numbers: by addition of fertile ovules to spikelets, pods, etc; by increase of the size of the inflorescences (spikes, panicles, flowering branches); or by increase of the numbers of such inflorescences per plant.
- Increase in seed size.
- Breakdown of the camouflage coloration of seed coats (particularly in pulses).

Concluding remarks

A main reason for presenting this paper has been the realisation that there is a need to re-evaluate unconscious selection under domestication; and to better understand the role of this kind of selection in shaping cultivated plants. To day, the wild ancestry of many of our crops (particularly those domesticated in Southwest. Asia and the Mediterranean basin) is already relatively well identified. The ecological specificities of several of these wild progenitors are also extensively studied. Moreover, the archaeological information on the rise of farming in these territories is quite extensive. In conclusion, compared to the situation some 15-20 years ago, more reliable sources of information are available today for critical evaluation of unconscious selection.

In other words, the time is ripe for:

- re-assessment of the ecological specificities and the main wild-type adaptations of selected progenitors;

and for

- further elucidation of the nature of the “ecological shifts” these plants were faced with - once taken into cultivation.

Finally the field is also in need of experimental tests and accompanied modelling of the kind pioneered by HILLMAN AND DAVIES (1990) in their study of non-shattering in einkorn wheat. Such new multi-discipline approach could be quite rewarding.

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Diversity in barley (*Hordeum vulgare*)

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Introduction

The magnitude and distribution of genetic variation, or genetic diversity, in wild plants is a major factor for a continuous evolutionary process in nature. The access to variable genetic material is also a prerequisite for early domestication, adaptation to new areas or habitats and for further progress in modern plant breeding. The same basic evolutionary mechanisms of mutation, recombination and selection are also operating under domestication and breeding but the speed of changes has increased considerably under cultivation in comparison to nature.

Since the beginnings of modern plant breeding and related research many different techniques have been applied to measurement of genetic diversity, such as morphological characters, adaptive traits and other characters of importance in agriculture (e.g., yield, resistance). In later years there has been a great number of studies on genetic diversity in various crops and wild species. In general the investigations treat:

- Material of a certain region or country;
- a selected sample of accessions from a world or larger regional collection;
- a particular taxon, group or type, such as landraces or cultivation types (winter or spring types, etc.);

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- a certain technique applied to certain material, such as some morphological characters, a particular trait (e.g., salt tolerance) or a certain molecular marker sytem;
- a particular taxon, group or type, such as landraces or cultivation types (winter or spring types, etc.).

However, as to our knowledge there is no major overview of available data from various fields to give a complete picture of the situation in a single species. This is the objective why the present authors, together with a number of specialists in various fields, took up the challenge to compile and compare various sets of available data for a particular crop, namely barley. This paper will conclude some of the major results from a larger publication under preparation (BOTHMER et al. 2002).

The reason for choosing barley was that, beside of being an important temperate cereal crop, it has also since long been used as a model object in genetic and cytogenetic research. There is, in addition, a wealth of data available for the present project.

Creation of diversity

Barley is one of the major crops of the world. Cultivated barley, *Hordeum vulgare* ssp. *vulgare*, belongs to the medium sized, temperate genus *Hordeum* with ca. 32 species (cf. BOTHMER et al. 1995). In various studies of phylogenetic relationships, barley appears to have its closest wild relatives in the Mediterranean area and SW Asia, where also the single representative of the secondary genepool, *H. bulbosum*, grows. The closest wild relative to barley, its immediate progenitor and single wild member of the primary genepool is *H. vulgare* ssp. *spontaneum*. It is still common in natural habitats and as a weed in the Middle East. The domestication process started here, and there is now conclusive evidence that barley, together with wheat and a few other species, were taken into cultivation and were fully domesticated ca. 10,000 years ago.

The progenitor, ssp. *spontaneum*, has a large genetic diversity (see below), and from this versatile genepool the cultivated forms emerged. The early domesticates were thus obviously genetically very diverse. The transition from a wild to a cultivated state implied a radical change of allele frequencies at certain loci. Rare alleles and new mutational events were positively selected for and got quickly established in the domesticated populations. A trait of prime importance in the wild state, such as brittle rachis promoting efficient seed dispersal, is of negative value under cultivation. Here a tough rachis is favoured, which allows the mature kernels to stay in place until the whole spike is ripe and can be harvested.

A number of such "key" genes have faced a heavy selection pressure in the early phases of domestication or later when adapting to other areas. Some of these genes in barley are:

- *brittle rachis*: regulated by two genes (*Btr1* and *Btr2*), it is one of the major traits to distinguish between Oriental and Occidental barley types;
- c*overed and naked kernels*: regulated by a single recessive gene;
- *seed dormancy*: quantitative inheritance;
- *growth habit* (spring or winter types): regulated by three genes;
- *kernel row* (two- or six-rowed types): regulated by one major gene.

The Fertile Crescent area in the Middle East is variable due to climatic, altitudinal, and habitat differences. This is reflected in the large morphological, physiological and functional adaptability in ssp. *spontaneum*, which facilitated colonisation of primary and secondary habitats in a range of most diverse environments (GRANER et al. 2002). Already at an early stage of domestication, a first differentiation of the genetic diversity took place. The success of domestication and early cultivation spread rapidly from the original areas. Seed material was brought by man to various areas along with the cultivation practices. Barley cultivation reached Spain ca. 7,000 years BP (Before Present), N Africa and Ethiopia ca. 8,000 years BP and northern Europe ca. 6,000 years BP. In each new place where cultivation was brought the material was exposed to new climatic and edaphic conditions. Due to the initial large genetic variation in barley together with accumulation of new mutants and recombinants, the crop became locally adapted. This has been a gradual process over millennia and it is the basis for the creation of a multitude of locally adapted, genetically variable landraces.

Over the years and in different regions there has also been conscious selection by farmers for various criteria, such as taste, texture and other quality characters as well as for yield. Since barley is a crop with multipurpose uses selection has been made for the various uses further adding to diversity in older and newer lines. The major uses are:

- *human consumption* – here naked kernels are preferred, still used particularly in high altitude areas of C Asia;
- *feed* – selection for particularly high protein content lines has been made;
- *malt* – brewing is a very old knowledge to man (at least 4,000-5,000 years BP in Egypt), promoting high enzymatic activity;
- *health products* – such as pearled barley in SE Asia, barley for tea production in Japan, and "barley grass" (seedlings of barley) in Europe.

The migration and adaptation of barley to new environments resulted in a complex picture of ecogeographical types over the world, recognised by morphological, agronomical and adaptive traits (cf. KNÜPFFER et al. 2002).

Modern plant breeding started with simple selections from the older landraces. The current cultivars of Europe are to a great extent the result of the earlier, first selections and cross-breeding of a restricted number of lines. This means that modern varieties would be genetically depauperated and have a very narrow genetic base (see below). Exotic material has had a restricted use in breeding in Europe, but could nevertheless have had a considerable influence on the present genetic diversity pattern in pedigrees of modern cultivars (FISCHBECK 2002).

Present status of diversity in barley

Even though there is a wealth of data accumulating on genetic variation in cultivated barley it is not an easy task to obtain an overview of the entire diversity pattern in time and space. This shortcoming has several reasons:

- Although a considerable amount of marker data has been generated by now, individual data sets pertain only a restricted number of accessions and are usually based on a unique marker set. Hence, it is at present not possible to pool data in order to further complete the picture of structure and diversity of the genepool (GRANER et al. 2002).
- It is difficult to get a good estimate of the diversity in cultivated barley, since continuous breeding efforts have caused the formation of regional and temporal diversity patterns, which reflect several factors, such as cropping system (winter *vs.* spring forms), end use (feed *vs.* malt) and the strategy of individual breeders to rely on distinct progenitors (FISCHBECK 2002).
- Different sets of data, even based on the same material, may show conflicting pictures such as diversity for resistance or adaptive traits compared to a marker system. This may be caused by different selection pressures.
- No attempts have been made to develop modern bioinformatics methods to cover these areas.

Despite methodological shortcomings and other difficulties it is, nevertheless, possible to elucidate some obvious tendencies in the amount and distribution of genetic diversity in barley. Wild and weedy forms as well as primitive, domesticated material are still abundant in certain areas. Ssp. *spontaneum* is common in nature in the Middle East, and landraces are frequently planted in parts of Central and SW Asia as well as in N Africa, where barley is a staple food. The genetic diversity shows a significant decrease so that the variation in wild barley (ssp. *spontaneum*) is higher than in landraces and even more so than in modern varieties, as shown in several studies (cf. GRANER et al. 2002). The larger variation in ssp. *spontaneum* is partly due to the higher degree of outbreeding (up to 10-12 % of outcrossing has been reported, cf. BROWN et al. 1979) than in cultivated material (usually < 1 %). Ssp. *spontaneum* originally had a very large diversity due to adaptation to the versatile environments in the Fertile Crescent. The wild form is obviously particularly variable in Israel, but collections and investigations of material from other areas have been carried out to a much lesser extent. According to several studies by the Israeli research group of Prof. E. Nevo there is a very strong correlation between diversity and stress tolerance (e.g., to salt and drought). Plants in a stressful environment are significantly more variable than plants growing under more optimal conditions (cf. PAKNIYAT et al. 1997).

Also for landraces a number of studies based on isoenzymes, hordeins and various molecular markers, indicate a large and often geographically related variation pattern. Particularly variable and subject to clinal differentiation, such as to altitude, climate or other environmental conditions, is material from Ethiopia. A comparison between ssp. *spontaneum* and landraces showed a significant pattern (Table 1).

Tab. 1: Variation in isoenzymes in barley landraces and ssp. *spontaneum* (after NEVO et al. 1986)

	No. of alleles detected	**Loci without polymorphism**
Landraces		
Europe	44	10
Iran	40	5
ssp. *spontaneum*		
Iran	49	6
Israel	79	0

Several studies show that there generally has been a gradual and steady loss of alleles over time, particularly in modern and high bred varieties. The so-called genetic erosion should thus have been regularly depauperating the available genetic resources making the future breeding material more vulnerable. However, there are also other tendencies. In a study based on isoenzymes it was shown that new varieties (released after 1990) had a reduced variation amplitude compared to earlier varieties of Nordic and Baltic origin, which in turn had a more narrow variation than exotic landraces from C Asia (KOLODINSKA et al. 2001). This trend is also obvious in a broad survey of molecular markers by GRANER et al. (2002). These authors show that in most cases a new cultivar has a reduced diversity in comparison with the foundation lines.

The tendency of genetic erosion is, however, not conclusive. Also in the above mentioned study by GRANER et al. (2002) some modern varieties actually showed an increased diversity in some of the markers as compared to the foundation lines. Similar results were reported on Nordic and Baltic material by KOLODINSKA et al. (2001) based on inter-SSR and by MANNINEN and NISSILÄ (1997) based on RAPDs.

In areas where older and newer material is grown together, introgression and sowing seed kept by farmers may pertain and even increase diversity. Such is the situation on Sardinia where the common and variable landrace ('S'orgiu sardu'), grown over the entire island for a long time shows evidence of having obtained genes from earlier cultivated, more advanced varieties (PAPA *et al.* 1998).

In many areas a few barley cultivars can be dominating in time and space. So, for example, is the Turkish cultivar 'Tokak', released already in 1937, grown annually over three million hectares for many years. The Russian cultivar 'Moskovsky 121', released in 1977 is grown annually over 2 million hectares since then (FISCHBECK 2002). This trend increases the vulnerability and decreases the diversity. If the trend of large acreage over many years is kept too long it will drastically influence the replacement of cultivars and the use of higher number of cultivars per acreage. This will add to the genetic erosion. There may be several reasons for the genetic erosion in barley (FISCHBECK 1992):

- The limited number of landraces used to select superior genotypes during the initial phase of breeding;
- a small number of outstanding cultivars used as progenitors in breeding programmes;
- limited use of exotic germplasm.

Future development of diversity in barley

Barley is well represented in the world's genebanks with ca. 378,000 accessions reported (HINTUM 2002). However, duplications are common and of the reported number it is at present not possible to estimate the actual number of unique accessions. Moreover, due to the lack of overview we can neither indicate the "white spots" in current holdings, i.e. from which areas or of which types no or restricted material is available and which are in urgent need for intensified collecting or monitoring.

Currently, despite that there has been and still is an ongoing genetic erosion, it is not known how large (or important) this is. It is also amazing that there is still variation left in advanced material, and new genotypes can be obtained by crossing closely related elite lines. This techniques has been used for more than 100 years and one would expect that the genetic variation since long had been exhausted. It thus appears that the conventional breeding process can be continued without an urgent need for a general increase in the level of genetic diversity since a review of 80 years of cross-breeding in barley in Europe shows no indication of a reduction in RFLP diversity (FISCHBECK 2002).

Based on the progress in cross-breeding over time, a special outlook for the future of barley breeding can be made. Actual progress has been obtained from successful crosses between closely related parents and a hypothesis of *'de novo'* diversity has been raised for explanation (RASMUSSON and PHILLIPS 1997).

The key questions for the future development of diversity are:

- How large is the genetic erosion and is it an important factor or not?
- How much of new recombination (new genotypes) can be created from existing elite material?
- How much of “new” alleles are available in wild or exotic genetic resources?
- How will the future agriculture look like? Will there be a higher number of cultivars available for particular quality or other purposes or for organic farming?

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Diversity of African vegetable *Solanum* Species and its implications for a better understanding of plant domestication

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Abstract

The domestication of *Solanum* vegetables in Africa depended on the development of agricultural systems and the availability of suitable wild or introduced species. *Solanum aethiopicum* (scarlet eggplant) and *S. macrocarpon* (gboma eggplant) are African, *S. melongena* (brinjal eggplant) was introduced from Asia, but its closest relatives are African, and *S. scabrum* (one of the black nightshades) was probably domesticated in Africa. Studies of these eggplants have shown that domestication has produced a vast increase in morphological diversity of the cultigens compared with their wild ancestors, yet the diversity in molecular markers has not increased. This morphological diversity in eggplants and all other domesticated plants is mostly attributable to so-called recessive genes, and can be explained by the loss of existing gene function or regulation rather than being due to new genes. This paradigm may also help explain some of Vavilov's hypotheses, and has practical implications for plant breeding, taxonomy and core collections in genebanks.

Introduction

Over 100 species of *Solanum* are indigenous to Africa, and several of these have been developed as vegetables there. This paper discusses the diversity of these domesticates and their close relatives, considers their evolution, and attempts to explain it.

Relatively little is certain about the development of agriculture and the domestication of crop plants in Tropical Africa, which is the vast area between the Sahara Desert on the Tropic of Cancer and the Kalahari Desert on the tropic of Capricorn. It is generally accepted that agricultural systems based on grain crops in the Fertile Crescent in Western Asia were taken to Egypt and Ethiopia, providing the bases of the great civi-

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lisations there. They also spread westwards through the then green savanna habitats of the Sahara and Sudan 5,000 or more years ago, thus developing and culminating in the great sub-Saharan African empires of Ghana, Kanem-Bornu, Mali and Songhay in the 9th to 16th centuries (DAVIDSON 1972). As it spread, new grains indigenous to Africa were domesticated and integrated into this agricultural system, and likewise many new vegetables were added. How much indigenous agriculture had been developed previously in Africa is very uncertain, especially for root crops such as yams and other vegetables in the hot and humid areas where no archaeological remains survive (HARLAN et al. 1976, HAWKES 1983).

For most of Africa, crops have been grown traditionally in mixed cultivation in gardens or in small fields, the women farmers carefully maintaining their own genetic resources from one season to the next (LESTER et al. 1990). This has produced land races or primitive cultivars adapted to local conditions and preferences, and with great diversity across Africa. European taxonomists, unaware of domestication processes, have distinguished these as very many different species. In the case of *Solanum*, these reduce to just four cultigens, namely *S. scabrum* Mill., *S. melongena* L., *S. macrocarpon* L. and *S. aethiopicum* L., together with their related wild species. These are very distinct taxa, and although hybrids between *S. melongena*, *S. macrocarpon* and *S. aethiopicum* are possible, they have low fertility (DAUNAY et al. 1991). These three species are the brinjal, gboma and scarlet eggplants, respectively (LESTER 1986). Here, as elsewhere, crossability is not congruent with either phenetic or molecular similarities. *S. melongena* crosses more easily with *S. aethiopicum* yet it is more similar to *S. macrocarpon* in many morphological characters. Likewise *S. melongena* crosses easily with *S. cerasiferum* Dunal and with *S. sessilistellatum* Bitter to produce fertile F1 hybrids (DAUNAY et al. 1998), yet it is distant from them according to AFLP analyses of DNA. In this treatment we use the morphological species concept (based on phenetic discontinuities), as applied in the new "Mansfeld's Encyclopedia" (LESTER and HAWKES 2001), which is the most useful for herbarium taxonomists, rather than the biological species concept (based on reproductive isolation), which may be more useful for plant breeders. The present treatment has to be brief, but for more extensive treatments of this subject, we recommend the publications of FAO (1988), DAUNAY et al. (2001a), SCHIPPERS (2000) and LESTER and HAWKES (2001), which also treats potatoes and other *Solanum* crops introduced into Africa from South America.

The four African vegetable *Solanum* species

1. *Solanum scabrum* Mill., etc. – Black Nightshades

Solanum nigrum L., the black nightshade, type species of *Solanum* L. subgenus *Solanum* section *Solanum*, is a well known Eurasian weed, but its name is often misapplied to related species, thus confusing the literature. The centre of origin of these species is South America, but many have spread into Africa. The meticulous and extensive taxonomic, cytogenetic, and other investigations of Edmonds (see EDMONDS AND CHWEYA 1997, LESTER and HAWKES 2001), have reduced the taxonomic confusion of these species and explained their evolution to a large extent. Also DNA analyses (DEHMER 2001) are beginning to help, but here we refrain from further comment on the diversity of this extremely difficult complex of species.

Several species of section *Solanum* grow as weeds throughout Africa, or are cultivated (EDMONDS and CHWEYA 1997, BUKENYA and CARASCO 1999). The leaves provide a useful green vegetable when boiled like spinach (SCHIPPERS 2000): this cooking also reduces the amounts of potentially toxic steroid alkaloids. The most important species is *S. scabrum* which shows considerable diversity in vegetative features, as well as in the fruits which are also eaten (SCHIPPERS 2000). *S. scabrum* was probably domesticated in northern Nigeria, where perennial forms grow wild (GBILE, pers. comm.).

2. *Solanum melongena* L. – Brinjal Eggplant

Although *S. melongena* was domesticated in South-east Asia rather than in Africa, many closely related wild species are indigenous in Tropical Africa, and the crop is grown extensively in both northern and southern Africa for the fruits that are cooked in many ways (DAUNAY et al. 2001a).

Solanum melongena is the type species of *Solanum* L. subgenus *Leptostemonum* (Dunal) Bitter section *Melongena* (Miller) Dunal (CHILD and LESTER 2001). BITTER (1923) classified it into series *Incaniformia* Bitter subseries *Melongena* Bitter, but his allocation of species to subseries *Campylacantha*, *Euincana* and *Melongena* is not acceptable now. Within series *Incaniformia* there are about 12 African species, which Bitter differentiated as 28 species, but other authors have lumped 24 of these together as the *S. incanum* complex. Some of these were studied intensively by Hasan (LESTER and HASAN 1991, DAUNAY et al. 2001a), leading to the recognition of four widespread and important morphological species [3]:

A - *S. campylacanthum* Hochst. ex A. Rich.
B - *S. delagoense* Dunal
C - *S. incanum* L., *sensu stricto* and
D - *S. lichtensteinii* Willd.

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[3] Lester and Hasan misapplied the name *S. panduriforme* E. Meyer ex Dunal to species B - *S. delagoense*, and did not restrict species *S. lichtensteinii* to southern Africa.

Other allied but distinct morphological species recognised by LESTER et al. (1990) but not available to LESTER and HASAN (1991) are *S. trepidans* C.H. Wright, *S. panduriforme* E. Meyer ex Dunal, *S. cerasiferum* Dunal, *S. beniense* De Wild., *S. aureitomentosum* Bitter, *S. stellativillosum* Bitter, and *S. lachneion* Dammer. Thus there is a considerable diversity of these species in Africa that are very closely related to *S. melongena*, but also many other apparently less closely related species have been crossed with it with more or less success (DAUNAY et al. 1991, 1998, 1999).

An extensive crossing programme onto *S. melongena* as female, achieved almost as high a percentage of seeds using pollen from *S. incanum* and *S. lichtensteinii* as with pollen from other accessions of *S. melongena*, but the fertility of these interspecific hybrids was lower. In general, hybrids of *S. campylacanthum* and *S. delagoense* with *S. melongena* were more difficult or impossible to obtain, whereas crosses of *S. campylacanthum* with *S. delagoense* were highly fertile, as also were hybrids of both *S. campylacanthum* and *S. melongena* with *S. cerasiferum* (DAUNAY et al. 1991, 1998, 2001b, LESTER and HASAN 1991, OLET and BUKENYA 2001).

Numerical taxonomy of morphological characters showed that the four species studied by HASAN (LESTER and HASAN 1991) were fairly distinct, and this was shown clearly by AFLP analyses of DNA (MACE et al. 1999). The distinction between *S. incanum* from north-eastern Africa and *S. lichtensteinii* from southern Africa, which was treated as a variety of *S. incanum* by Bitter, was very clear. Chloroplast DNA (SAKATA and LESTER 1994) showed an even greater separation, whereas there was less separation between *S. campylacanthum* and *S. delagoense*, which might be considered as a single biological species. Studies in Uganda have shown tremendous morphological variation in *S. campylacanthum*, there called *S. incanum*, yet crossing experiments showed it to be a single biological species (OLET and BUKENYA 2001).

The above data prove that even though they have many morphological similarities, at least *S. incanum*, *S. lichtensteinii* and *S. campylacanthum* are very distinct species and should not be confused, as they have been in the past. Furthermore, although superficially similar to *S. incanum* and *S. melongena*, *S. marginatum* L. f. from Ethiopia is not closely related, as proved by spermoderm SEM, crossability, chloroplast DNA and DNA analyses by AFLP (LESTER and HASAN 1991, DAUNAY et al. 1991, SAKATA and LESTER 1994, MACE et al. 1999).

Numerical taxonomic studies of many accessions of *S. melongena* itself (LESTER and HASAN 1991) showed considerable morphological diversity, more than that within or even between *S. campylacanthum* and *S. incanum* for instance, even though the data used did not include any of the vast diversity in fruit characters (DAUNAY et al. 2001a, plate IX, 1). However, all these accessions of *S. melongena* were highly interfertile, and there were no greater variations shown by AFLP analyses of DNA, nor by isozymes and other molecular markers, than the variation within *S. campylacan-*

thum or *S. incanum* (ISSHIKI et al. 1994, SAKATA and LESTER 1994, KARIHALOO and GOTTLIEB 1995, MACE et al 1999). Therefore all of the domesticated and weedy Asian forms of *S. melongena* may be treated as a single species.

The discrepancy between great morphological diversity, especially in fruit characters, yet low diversity in molecular markers, is particularly obvious amongst the cultivars of *S. melongena*, both primitive and advanced. The wild ancestor is fairly prickly and has spherical fruits about 2.5 cm diameter, pale green with darker green stripes or reticulations when immature, ripening directly to orange yellow. The primitive cultivars are less prickly, and have larger spherical or ovoid fruits that may be white when immature, whereas more advanced cultivars have few or no prickles and have much larger fruits of many shapes, from depressed spherical through obovoid to very long and serpentine, and of many colours when immature, from green to white to pink to violet to almost black, and patterned or not. The fruit weights range from a few grams to a few kilograms. Although primitive *S. melongena* is fairly similar in morphology and in most DNA and isozyme analyses to some African species, especially *S. incanum* or even *S. lichtensteinii*, there are some clear differences in several molecular markers, such as the Sal I pattern from chloroplast DNA analyses (SAKATA and LESTER 1994). Altogether these various data indicate that from the several species that evolved in Africa, one, which was probably *S. incanum*, gave rise to a distinct species which spread to South-East Asia as the wild ancestor of *S. melongena* (LESTER and HASAN 1991). This may be called *S. cumingii* Dunal as a distinct morphological species, although plant breeders may include it within the same biological species as *S. melongena*. This taxon is known from areas in and around Vietnam, probably even as a truly wild plant of primary vegetation. It seems that from this rather small gene pool were produced the domesticated forms of *S. melongena*, which developed great morphological diversity but relatively little diversity in molecular markers (DAUNAY et al. 2001b). Mapping the chromosomes with molecular markers has therefore necessitated a cross between *S. melongena* and *S. linnaeanum*, a rather distant South African relative (DAUNAY et al. 2001b, DOGANLAR et al. 2002a).

3. *Solanum macrocarpon* L. – Gboma Eggplant

Solanum macrocarpon (classified in *Solanum* subgenus *Leptostemonum* section *Melongena* series *Macrocarpa* Bitter) is cultivated widely throughout tropical Africa, especially in the more humid regions. The glabrous leaves are a very important green vegetable, cooked like spinach, and the large fruits are cooked in stews with meat and other vegetables (SCHIPPERS 2000). There is much diversity in both leaves and fruits. The fruits are 3-12 cm in diameter, spherical or depressed spherical, usually green, whitish or purplish or with lighter markings when ready for eating, but at physiological ripeness they turn yellow to orange or brown, and the surface may crack (DAUNAY et al. 2001a, plate IX, 3). The calyx is very large. Many cultivars are robust perennials with large deeply lobed leaves, but other cultivars, especially in West Africa, are smaller much branched herbs with smaller often simple leaves and the young shoots are picked as a 'cut-and-come-again' vegetable.

The wild ancestor is *S. dasyphyllum* Schum. and Thonn., a rather different looking plant, covered with hairs and prickles, which occurs wild throughout tropical Africa. It originated probably in East Africa, and spread from there. The place and mode of domestication is not certain, but fruits of *S. dasyphyllum* are used for folk medicine (BUKENYA and CARASCO 1999). Although most forms of *S. macrocarpon* and *S. dasyphyllum* are distinct, and are conveniently treated as distinct morphological species, they are completely interfertile, and intermediate forms occur. Thus they can all be regarded as a single biological species (BUKENYA and CARASCO 1994). DNA analyses by AFLP showed four accessions of these taxa to be very similar to each other and completely distinct from *S. sessilistellatum*, *S. cerasiferum* or any other species analysed (MACE et al. 1999). However, many more accessions of all kinds and from all parts of Africa should be analysed using molecular markers, to clarify their evolution and to find their closest relatives.

4. ***Solanum aethiopicum*** **L. – Scarlet Eggplant**

Solanum aethiopicum (classified in *Solanum* subgenus *Leptostemonum* section *Oliganthes* (Dunal) Bitter) is a very important vegetable throughout tropical Africa, especially in the less humid regions: in the Ivory Coast *S. aethiopicum* and *S. macrocarpon* are second only to okra (*Abelmoschus* spp.) in production (LESTER et al. 1990). The fruits are scarlet red when mature, but the green immature fruits of Gilo and Kumba Groups are stewed with other vegetables and meat or other protein rich foods, or even eaten raw, whilst the glabrous leaves of Shum and Kumba Groups are boiled as green vegetables, like spinach (SCHIPPERS 2000). There is a vast diversity of shapes and sizes of fruits (DAUNAY et al. 2001a, plate IX, 2), and also of leaves. According to their usage, four cultivar-groups are recognised, which were treated previously as several different species (BITTER 1923, LESTER 1986, LESTER et al. 1986, LESTER and NIAKAN 1986, DAUNAY et al. 2001a, LESTER and HAWKES 2001). These are as follows:

1. *S. aethiopicum* Gilo Group typically has fruits the size and shape of hen's eggs, but there are very many other shapes (depressed spherical to ellipsoid) and sizes (2-8 cm diam.). The leaves are hairy and are not eaten.
2. *S. aethiopicum* Shum Group is typically a short much branched plant with small glabrous leaves and shoots that are plucked frequently as a green vegetable. However, the small (1.5 cm diam.) very bitter fruits are not eaten.

3. *S. aethiopicum* Kumba Group has a stout main stem with large glabrous leaves that can be picked as a green vegetable, and later produces very large (5-10 cm diam.) grooved fruits that are picked green, or even red, that store well, and are stewed or eaten raw.
4. *S. aethiopicum* Aculeatum Group are ornamental plants, probably produced in Europe by hybridisation between *S. aethiopicum* Kumba Group and *S. anguivi*. They are prickly and hairy, but with fairly large grooved fruits. Under the synonym *S. integrifolium* they have been used for disease resistance breeding.

The wild ancestor of all these cultivar-groups is *S. anguivi* Lam., a very prickly and hairy shrub of disturbed savanna woodland habitats throughout tropical Africa. Semi-cultivation and semi-domestication have produced *S. distichum* Schum. and Thonn., which is like *S. anguivi* but without prickles, and has scarlet fruits 1.0-1.5 cm diam., held erect or pendant, which may be used for medicine or as a bitter flavour in stews (as also may those of wild *S. anguivi*). Full domestication followed to produce the various cultivar-groups of *S. aethiopicum* (LESTER and NIAKAN 1986). It is debatable where to draw the taxonomic boundaries, but for herbarium taxonomy the distinctions given here are convenient, even though these taxa might all be considered as a single biological species. There are several closely related but poorly known wild species on mountains in Central Africa, as well as many other species of section *Oliganthes* in East and South Africa (AL-ANI 1991).

Domesticated traits of eggplants, and their genetics

The morphological diversity within *S. aethiopicum* has been analysed extensively for over 100 accessions with 106 characters, by numerical taxonomy (LESTER et al. 1986). To a large extent the taxa defined above were vindicated, but also for each of 36 characters it became possible to deduce the primitive state typical of *S. anguivi* and the derived states in the cultivar groups. Thus domestication has involved changes such as from perennial, prickly, hairy, shrubs, with large deeply lobed leaves to annual, non-prickly, glabrous, herbs, with smaller less lobed leaves. *S. anguivi* has small five-partite flowers on thin pedicels with ten or more flowers in long inflorescences borne 100 cm or more high, whereas some domesticates have larger, six to ten or more partite flowers, on thick pedicels, with only a few or one flower per inflorescence, borne as low as 20 cm above the ground. The fruits of *S. anguivi* are spherical, about 1 cm diam., with two locules separated by thin septa, held erect, with six to ten or more on a long rachis, uniformly green at first and then ripening to a scarlet, juicy, very bitter berry, that is easily detached. In contrast the fruits of various domesticates may be borne singly or a few together, pendant on thick pedicels, of many shapes and sizes, with 2-10 (-15) main locules, and even with inner locules, the septa are thick and placentas proliferate. They are variously green (uniform or striped), white or purplish at first, ripening to a scarlet, fleshy, sweet fruit, firmly attached to the pedicel even when fully ripe (LESTER et al. 1986). Despite this great morphological diversity, isozyme analyses showed relatively little diversity (LESTER and THITAI 1989) and even less was found in the chloroplast DNA (SAKATA et al. 1991).

The inheritance of some morphological characters was studied by making F1 hybrids between primitive *S. anguivi* or *S. distichum* and highly domesticated *S. aethiopicum* Gilo, Kumba and Shum Groups, and then analysing the F2 generations (LESTER and THITAI 1989). In general the F1 plants showed greater similarity to the primitive parent in many more characters than to the highly domesticated parent. In some cases the F2 showed simple dominance of the wild-type character state, such as for presence of leaf prickles or presence of star hairs, whereas density of star hairs showed incomplete dominance. However, other characters appeared to show dominance in the F1, but the F2 proved that the inheritance was more complicated, such as for petiole anthocyanin colouration, inflorescence length and flower number. This probably also applied to several fruit characters, but unfortunately it was impossible to analyse the F2 for these characters. For some other characters, such as sepal number, the F1 appeared to be intermediate, but the F2 showed a skewed distribution towards the wild type, and leaf prickle number even showed transgression. Most of the F1 hybrids showed heterosis or overdominance in plant height. The tendency to a greater similarity to the wild parent has also been observed in hybrids between *S. melongena* and many different wild species (DAUNAY, unpublished). However, hybrids between different domesticates have sometimes produced unexpected characters. A cross between *S. aethiopicum* Kumba Group and *S. macrocarpon*, both of which lack prickles or hairs, produced a prickly though not hairy F1 hybrid. Some F2 progeny from *S. melongena* crossed with *S. macrocarpon* were very prickly although neither parent was. Furthermore, a cross between cultivars of *S. melongena* and *S. aethiopicum* Gilo Group, each with few-flowered inflorescences, produced hybrids with long multi-flowered inflorescences, as in both the wild ancestors (DAUNAY and LESTER, unpublished). These cases illustrate atavisms, as observed long ago by Darwin and others, and might be explained by complementation of different recessive genes (DARWIN 1868, LESTER 1989).

Loss of gene function: a new paradigm for the domestication process

Considerations of the diversity of African vegetable *Solanum* species, and how they have evolved from their wild ancestors, have led to conclusions that have implications not only for eggplants, but for all domesticated plants (LESTER 1989).

For both scarlet and brinjal eggplants (*S. aethiopicum* and *S. melongena*) it has been shown above that the domestication process has not only produced cultigens that are very different in morphology from their wild ancestors, but also that these cultigens display a vast range of diversity within themselves. On the other hand, wherever studies of molecular markers such as isozymes and DNA have been made, the diversity within the cultigens has been found to be little or no greater than that of the wild ancestor. This situation, which is shown diagrammatically in Figure 1, is also exemplified clearly by tomato (*Lycopersicon esculentum*), pepper (*Capsicum annuum*), and especially by maize (*Zea mays*) (DOEBLEY et al. 1987, LESTER 1989, LEFEBVRE et al. 2001). This seems to be a general rule for all domesticated species of plants (except perhaps those derived from interspecific hybridisation). This paradox, of the vast and deviant morphological diversity of cultigens compared to their wild ancestors on the one hand, and the minimal increase in diversity of molecular markers such as DNA and isozymes on the other, demands an explanation.

To begin with, let us consider some of the morphological changes that have occurred during the domestication of *Solanum aethiopicum*. LESTER (1989) stated that "In *Solanum anguivi*, the wild ancestor of the scarlet eggplant, development of flowers and subsequent fruits is rapid and apparently under close genetic control: the ovary is composed of precisely two locules, and after pollination it enlarges to exactly 1 cm diameter and then stops. The colour changes rapidly from green to red, the flesh

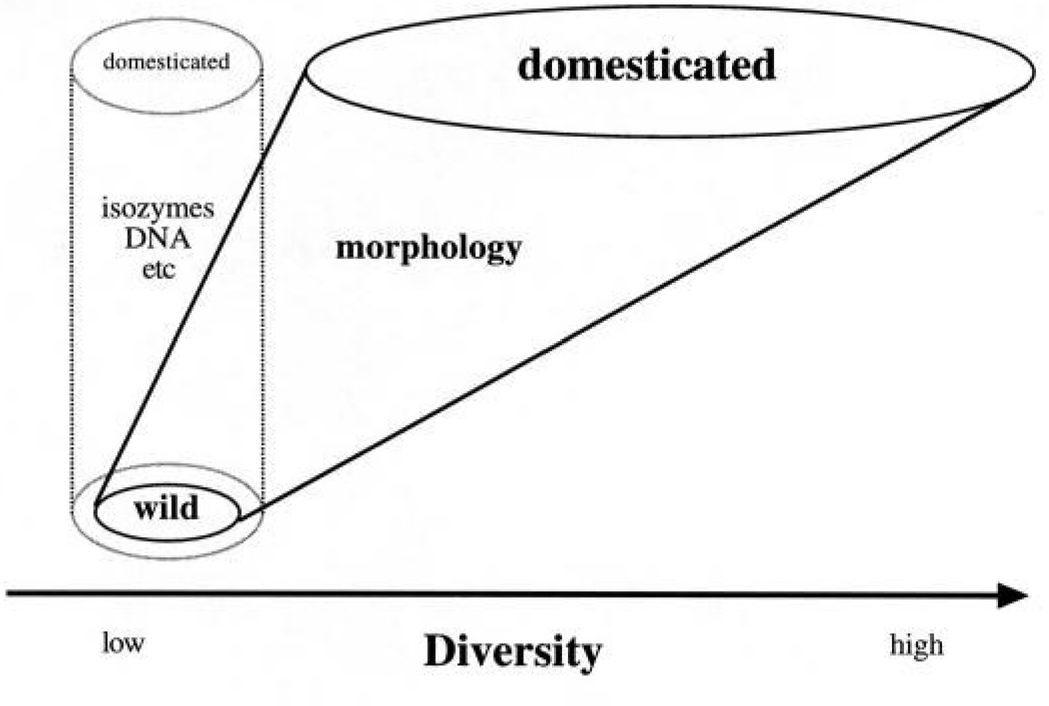

Fig. 1: Diagram showing that in morphology a domesticated species is different from its wild ancestor and displays much greater diversity, whereas in isozymes, DNA or other molecular markers the diversity remains much the same

disintegrates into a juice, and an abscission layer develops between the fruit and the stalk. It is well adapted to consumption by birds and is effectively dispersed by them (LESTER et al. 1986). In contrast, the highly domesticated derivative, *Solanum aethiopicum* Kumba Group, has an ovary with many outer locules and also several inner locules. After pollination it grows irregularly to about 5-10 cm diameter, the colour turns slowly to scarlet, but the fruit stays strongly attached to the stalk and the flesh stays firm even after many months of storage. Some of these and several other changes during domestication of *S. aethiopicum*, notably loss of prickles and loss of stellate hairs, have been proved more or less conclusively to be due to single or multiple recessive genes, the F1 hybrids resembling much more closely the wild parent than the domesticated one. The F2 progeny shows Mendelian segregation for the dominant wild type genes for simply inherited characters, or a skew distribution towards the wild type for some polygenic characters (LESTER and THITAI 1989)." It is particularly interesting that in this case the traits of domestication are mostly due to genes that are recessive to the dominant genes of the wild species. This is also true for most other cases that have been studied, such as pearl millet, barley, musk melon and many others (SCHWANITZ 1967, LESTER 1989, PONCET et al. 2000).

But what is a recessive gene? The classic definition of a recessive gene is that it is one that expresses itself only in the absence of the dominant gene, and a classic example is that of Mendel's wrinkled peas, where this character is only expressed in the homozygous recessive (rr), but not if the dominant round (R) gene is present. The difference between the wrinkled and round morphological characters is very clear to see. However, it has been found more recently that the basis of the wrinkled phenotype is the lack of a starch-branching enzyme, due to the non-function of the appropriate gene, due to the insertion of some extra DNA that appears like a transposable element (LESTER 1989). Thus in this case, and in many others where investigated, the so-called 'recessive' gene is in fact an incapacitated normal gene, incapable of expressing itself at all, and therefore is a null allele in terms of biochemical genetics. This loss of gene function is easily appreciated as the basis of many traits of domesticated plants, such as loss of articulation in the infructescence of cereals and other plants and hence the loss of the natural dispersal mechanisms, which thus enables humans to harvest the crop well. Another example is the loss of seed dormancy mechanisms, which result in all the seeds germinating together after they have been sown. These and many other traits of domestication syndromes (HAMMER 1984, in KOINANGE et al. 1996) can easily be explained in the same way, for example the loss of protective mechanisms such as prickles, or the loss of secondary metabolites that inhibit or disable herbivores, or even the loss of pigmentation and patterns in flowers and seeds. The gain of pigmentation in domesticates, such as purple potato tubers or eggplant fruits may also be due to altered or lost gene regulation, so that the synthesis of anthocyanins, which in the wild ancestors was restricted to the corolla, now occurs also in the tubers or fruits. Apparently new colours such as a change from red to yellow, are often due to lack of production of a dark pigment thus revealing a paler pigment which previously was not obvious although it was already there, as can be proved by chromatography. Truly novel pigments may result from the interactions of biochemical pathways previously restricted to different tissues or organs but now reacting together in the same tissue. Loss of genetic control may also be significant in the pre-adaptation of ecological weeds. Many wild species have rigid genetic control appropriate to plants in strict natural habitats: they show narrow plasticity and cannot respond to favourable conditions by greater growth. However, many weedy species seem to have less rigid genetic control, allowing them to be very plastic and adaptable so they can take advantage of favourable conditions in disturbed and unpredictable habitats, especially cultivated fields. This pre-adaptation has allowed some weeds to become the progenitors of all our annual crop plants: tomato is a prime example (HAWKES 1983).

However, a major phenomenon of domestication remains to be explained and that is 'gigantism' or 'Gigaswuchs' (SCHWANITZ 1967), where particular parts of the plant, which we use for food or ornament or other purposes, grow much bigger than in the wild species, and often in an irregular way. This is obvious in the change from the small spherical berry of *S. anguivi* to the monstrous fruits of *S. aethiopicum* Kumba Group. Although of course plant breeders may think that they are breeding for bigger and better crops (which they are), we can realise that these changes can also be due to loss of gene function, particularly in regulator genes. Thus in wild *S. anguivi*, after pollination and fertilisation, plant hormones are produced and the ovary grows. However, at the appropriate time hormone production is turned off and this growth is stopped, resulting in rapid production of a neat, small, red, juicy, easily detached berry exactly 1 cm in diameter, precisely the right size, colour and composition for the birds that eat these fruits and disperse their seeds in the natural environment. On the other hand it seems that in *S. aethiopicum* Kumba Group, hormone production is not turned off, and growth is not stopped but continues and thus produces the monstrous fruits. Similar explanations, involving loss of gene function and/or regulation probably apply to other cases of gigantism in domesticates (LESTER 1989). This also has implications for our understanding of QTLs (quantitative trait loci): if increased size results from loss of gene function or regulation, then each QTL we seek is the absence rather than the presence of a factor. Thus gigantism and various other characteristics of domestication might be accounted for by loss of genetic control mechanisms, which could explain in part the phenomenally rapid evolution of crop plants over a mere few thousand years (LESTER and THITAI 1989). (The genetics of disease resistance is much more complicated and we do not attempt to explain that here.)

The discussion above, perhaps a new paradigm (i.e., a different conceptual framework), can help us further to explain the spectacularly rapid domestication of crop plants, and to consider whether they should be classified in the same way as wild species, and even whether molecular markers are unlikely to help with such classification. It is generally appreciated that the evolution of wild species is a very slow process, involving the production of mutations, resulting in variant phenotypes, followed by natural selection of the fittest. This process is usually slow, and may take millions of years for the production of new species. In contrast, all the diversity of our domesticated crops has been developed within the past 10,000 years or so. Of course this rapid development has been favoured by the rapid life cycles of annual crops, by the abundance of individuals in these crops, by the ease of gene exchange in monoculture crops, by the founder effect and genetic drift in small scale agriculture, by the reduction of the constraints of natural selection when these crops are cultivated and thus the survival of relatively unfit novelties, and by the artificial selection by humans, whether conscious or unconscious (HAWKES 1983). Most of these points apply also to somatic mutations in vegetatively propagated crops such as potatoes and yams. However, underlying all of this may also be the ease of production of novelties by loss of gene function or regulation as emphasised in this paper, as well as the fact that a few mutations can generate the enormous changes of a domestication syndrome (KOINANGE et al. 1996). Because the abundant phenetic novelties in domesticated plants produce different patterns of variation than in wild species, taxonomists have recently produced the International Code of Nomenclature of Cultivated Plants in addition to the long established International Code of Botanical Nomenclature. That domesticated plants display much greater diversity in phenetic traits than in molecular markers, especially amongst advanced cultivars has been shown clearly for *Capsicum* using 41 morphological traits, 544 RAPD markers, and 378 AFLP markers (LEFEBVRE et al. 2001, Fig. 2b). This also means that molecular markers have less resolving power than do phenetic traits for distinguishing cultivars, and therefore should only be used with great caution when selecting representative core collections in genebanks. However, for comparing genome evolution amongst distantly related taxa (e.g., eggplant, pepper, tomato, potato) these molecular tools are very powerful (DOGANLAR et al. 2002a, b).

A further twist on our path may bring us briefly back to Mansfeld, and especially to Vavilov. The Law of Homologous Series of VAVILOV (1951) was based on the observation that similar morphological traits were developed in unrelated crop species within particular geographical areas, such as “non-ligulate rye as well as wheat in Bokhara and naked-grained forms of barley, oats and millet in China” (HAWKES 1983). This suggests that the same new mutations have occurred in these different species, which would be surprising. If however these new morphological traits were the results of incapacitation of orthologous genes in the different species this is less surprising, especially now that we know the high degree of synteny in very different cereals (PATERSON et al. 1995).

Another observation by VAVILOV (1926, in HAWKES 1983), was that there is a higher incidence of ‘dominant’ genes at the centre of origin of a crop, and that more genes for disease resistance may be found there. This now seems obvious, that as a crop is domesticated, it loses the functions of various genes (including those for disease resistance), and as it becomes more domesticated it becomes more acceptable as a crop and is spread further away from its place of origin (LESTER 1989). *Solanum aethiopicum* Kumba Group, which occurs from Burkina Faso to Senegal (LESTER et al. 1986), seems to be a very good example of a crop that is cultivated almost entirely outside the natural range of its ancestor, *S. anguivi* (across Africa from Guinea to Ethiopia and south to South Africa), and that has lost the function of many of its genes. So, in order to find disease resistance to breed into *S. aethiopicum*, *S. melongena* and *S. macrocarpon*, we must look at the many wild African species, in particular those of sections *Melongena* and *Oliganthes* (DAUNAY et al. 1999), many of them being crossable with one or another of these three cultigens (DAUNAY et al. 1991, 1998).

Conclusions

In this paper we have attempted to introduce the reader to the four main African vegetable *Solanum* species, and also to the diversity within each cultigen and its close wild relatives. We have displayed the different levels of knowledge of each of these species. We have also emphasised the incongruities between morphological and molecular diversity both within and between the domesticates and their wild relatives. This has led us on to conclusions that most of the diversity in domesticates is due to loss of gene function or genetic control.

VAVILOV (1951) considered whether the genes for characters of domesticates were present in wild populations of the progenitors as rare recessive alleles which were then selected during domestication, whereas most others have presumed that the new traits of the domesticates are due to new or mutated genes with new biochemical functions (HAWKES 1983). We believe that Vavilov was almost right, in that there are not new genes but rather the loss of function of various genes of the wild progenitor.

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Molecular diversity studies in two large genebank collections of *Vicia sativa* L.

E. POTOKINA [1]

The *Vicia sativa* aggregate is a classical example of a complex of well separated taxa and derived forms, representing various degrees of phylogenetic divergence (HANELT and METTIN 1989). At the DNA level (RAPD, AFLP) their divergence is more evident (POTOKINA et al. 2000, 2002) than the divergence in morphological differences. We have estimated the intra-specific diversity of a member of the aggregate, *Vicia sativa* L. *sensu stricto*, common vetch, an economically important fodder crop, and compared this diversity with that of closely related, but phylogenetically separate taxa of the *V. sativa* aggregate. Using AFLP as a DNA fingerprinting method we investigated 673 accessions of *V. sativa* from the Vavilov Institute of Plant Industry (VIR, St. Petersburg) and 450 accessions from the Institute of Plant Genetics and Crop Plant Research (IPK, Gatersleben). The analysis is a first assessment of the intra-specific diversity of *V. sativa* stored *ex situ* on a scale of more than one thousand accessions.

AFLP patterns could clearly distinguish the various species of the *V. sativa* aggregate, and within the limits of the restricted samples from the various species apart of *V. sativa*, we have found potentially diagnostic AFLP bands. The situation is profoundly different within *V. sativa*, where no clear intra-specific patterns were found. Almost all alleles can be found throughout the whole area of distribution of the species, but with different probabilities. As a result, each eco-geographical region of distribution of *V. sativa* is characterised only by a set of frequent alleles, accompanied by some rare ”foreign” alleles. The degree of difference between the frequency compositions of the geographical regions seems directly related to the proximity between them.

The association coefficients of numerical taxonomy used in the most modern computer programmes for finding and displaying structures in multivariate data are based on the estimation of the proportion between the number of matches (mismatches) and the total sample size. These coefficients (Dice, Jaccard etc.) can be successfully used for the determination of groups, which show remarkable differences in terms of presence-absence of alleles (marked by AFLP or other methods). However, within strictly defined species we deal with eco-geographical

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groups, which could only statistically be circumscribed by differences in frequencies of dominant alleles in various parts of the area rather than by the presence of area-specific alleles. Here, we face the problem that no significant intra-specific grouping can be done using the association coefficients. Based on Smirnov's "originality index" (Smirnov 1969, Baev and Penev 1995), we suggest a new approach to highlight the structure of the intra-specific diversity of cultivated species stored *ex situ* (a more detailed description is being prepared for publication). This approach estimates the frequency of alleles in a given area and presumes that accessions originating from the same area might be characterised by a set of common or rare alleles. Thus, in each representation of accessions from the same area, the most common, special, and deviating accessions could be recognised. Based on the Smirnov specifity index, the genetic structure of the vetch collection of the VIR genebank was characterised. It can provide a solid base for the optimisation of the genetic diversity of *ex situ* collections and can be used to support of the efficiency of breeding programmes.

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The history of the medieval vegetable garden of the common man and woman: the poorness of descriptions and pictures

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Abstract

In search of depictions of medieval vegetables, a study of medieval vegetable gardens of the common man and woman was made. These gardens commonly occurred, but as they were probably too vulgar they were not described and depicted. In legal cases or financial accounts their presence has only been documented. Exchange of seed, seedware and knowledge between the common man and woman maintaining vegetable gardens and gardeners of vegetable gardens of castles, mansions, monasteries, abbeys and hospitals, and vice versa is described. It is suggested that links between both groups were frequent and strong, as most monks, although often entering the monastery at a young age, and servants of chatelains have grown up in 'common' families and 'received' their first practical training in gardens of the common man. During visits seed, seedware and knowledge will have been exchanged.

Introduction

After having studied the presence of vegetables and their forms in the 16th to 19th centuries as shown by paintings made in Flanders and North Netherlands (ZEVEN 1993, 1994, ZEVEN and BRANDENBURG 1986) it was decided to extend the study to vegetables of the Middle Ages. For Northwest Europe almost no vegetables as such have been depicted and described for this period. Therefore, our search was extended to studying medieval vegetable gardens, in the hope to find depictions and descriptions of vegetables in such gardens.

The result is that almost no descriptions and pictures are available. And if available they commonly refer to vegetable gardens of castles, mansions, monasteries, abbeys and hospitals. We may find information on these gardens in manuscripts and altar paintings (BEHLING 1967, HORST et al. 1984, MALO 1940). Vegetable gardens of the common man and woman, living in towns, in villages, on farms and market gardening enterprises, are little referred to (HADFIELD 1960, HYAMS 1970). Although these vegetable gardens also are earthly

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paradises, they have hardly been mentioned in the catalogue Aardse Paradijzen (Earthly Paradises) (JONG et al. 1996), a catalogue mainly referring to the period after 1500. The same is true for books on medieval gardens: those of the common people are hardly mentioned. For instance, the item 'vegetables' is mentioned by HARVEY (1981) in his Mediaeval Gardens, but no attention is paid to the medieval vegetable garden where these vegetables were grown. Exceptions are the paper by STANNARD (1985) in Medieval gardens, the book Tuinen in the Middeleeuwen (Gardens in the Middle Ages) edited by STUIP and VELLEKOOP (1992) and The Medieval garden by Landsberg (1995) where little information is presented. Therefore, we conclude that, in general, medieval vegetable gardens have not attracted the attention of garden historians. Maybe, for that reason, STANNARD (1985) explained to the participants of a congress of medieval gardens that there are archival records on 'plants and trees deliberately grown, maintained, and collected in medieval gardens primarily for food and/or medicine'!

In the present paper the histories of gardens of castles, mansions, monasteries, abbeys and hospitals are not discussed. Sufficient literature on these subjects is available. The same is true for archaeological records (VAN HAASTER 1992).

However, I wish to cite only one interesting item. After analysis of a refuse pit, discovered in the Old Town of Hull, it was concluded that near this pit, dated late-13th/early 14th century, a vegetable garden had occurred. Later, in the 16th century, this garden was exploited for growing fruit trees and shrubs (CRACKLES 1986).

Vegetable gardens of the common people

'Ordinary' vegetable gardens are cultivated by 'ordinary' people, i.e. of those living in towns, villages, hamlets and such. They (below referred to as the common man) grow their horticultural crops in their vegetable gardens. The common man was acquainted for many millennia with horticulture and agriculture. For instance, in South-Limburg, The Netherlands, some 7400 years ago the first farmers arrived from Germany (BAKELS 1997, ZEVEN 1997). These farmers had experience with growing crops on small fields, and they certainly will have used this experience when adding new crops to their crop assortment. Therefore, I am not convinced that the knowledge of growing of horticultural crops in West and Central Europe in the 8th and 9th centuries was introduced by Benedictine monks as is often claimed (FISCHER 1929). They, certainly, will have distributed new crops, such as cole crops, onion, leek, garlic and pea, from the south to the north. However, a crop such as perennial kale has very probably been distributed by the Romans (ZEVEN et al. 1996).

In vegetable gardens one may find vegetables, herbs and ornamental plants. The latter may have been grown to decorate churches and altars or used for festivities. Herbs are grown as true herbs, medicinal herbs and aromatic herbs. Several plants have more than one use. Also garden plants with other uses, such as being a source of pigment will have been grown.

There are many examples of plants grown for more than one purpose. An example is foxglove: it provides medicine, and it is an ornamental. And certainly, any volunteer plant will be accepted, even if it grows in the 'wrong' place. This is still being done.

A vegetable garden could have an economic base: the products could be home used and any surplus could be sold. Some may gradually have developed into market gardens.

Distribution of seed, seedware and knowledge

As the common men also had to work in gardens of the (original) land owner, they obtained good knowledge of the crops and quickly became acquainted with any new crop brought from elsewhere and with new techniques (BRUNNER and JARITZ 1985). After all, monks travelled from one monastery to another. They will have distributed appreciated crops and forms of them. The same is true for chatelains and their trains, which moved from one castle to another. However, monks grew up in families of various standings. They will have obtained their first horticultural experience in the (vegetable) gardens of their parents and neighbours. The same also is true for servants of the chatelains. Monks and servants will have visited their families from time to time, exchanging seed, seedware and knowledge between their original and present homes. Therefore, any new crop, any new type or any new technique will have quickly spread between the gardens of common men, monks and chatelains.

Keen 'common' gardeners will have observed any useful new form; they will have collected seed or seedware and also distributed the material among those interested, living nearby or far away. In a next season the latter will also have presented material to others, promoting the quick spread of new forms over large distances.

Such a new type at the end of the Middle Ages was the double columbine ('granny's bonnet') (LANDSBERG 1995). But not is known who was the first observer? The common man?

Demand for vegetables

The continuous increase of the number of people who did not produce sufficient food for themselves have pushed up the demand for vegetables. They lived especially in the towns and large villages. This increasing demand promoted the development of market gardens. As long as there was sufficient space within the town walls, market-gardening developed there. So some town men became market gardeners. In Flemish towns such changes took place in the 12th century. For instance, in a low-lying area within the walls of Brussels, the ‘broeken van Orsendaal’ (brooks of Orsendaal) were developed into a market garden area. The gardeners were named after the area as ‘broekoizen’, a name which became the name of the profession, even after the market gardeners moved to an area outside the town walls (LINDEMANS 1952). Elsewhere too, outside the walls of large towns market gardening developed. For instance, outside Arnhem, the Netherlands, near the Velperpoort (‘Velp gate’) in 1405 ‘orti caulinum’, i.e. cabbage gardens, were recorded (VERKERK 1992). Outside Deventer, also the Netherlands, cabbage gardens were leased in the years 1363 and 1368 (ZANTKUIJL 1974). In extending towns such gardens became situated within the new walls, and in due course, they were being used for house and street building.

Lack of studies of the history of vegetable gardens

One wonders why garden historians have not studied the gardens of the common man. One explanation is that garden historians are thinking only of gardens of delights, their neighbouring vegetable gardens, and of gardens of religious institutions. Gardens of the common man, although also composed of plant beds, and covering in total a much larger area than the first mentioned gardens are ‘too vulgar’ to write about. So, MCLEAN (1981) describing the English Domesday Book of the end of the 11th century wrote ‘The Domesday survey lists thousands of (---) yards and gardens attached to cottages or to town and manor houses of all sizes.’

A second explanation is the lack of descriptions and pictures of vegetable gardens. Were these gardens in the Middle Ages too ‘common’ to become described and depicted?

Poverty of descriptions of medieval vegetable gardens

When searching for data of Medieval times in archives one has to consult any record. Especially, ‘uncommon’ events have been described. For instance, in a chronicle by chaplain Trecpoel living near Maastricht, southern Netherlands, one finds that the winter of 1477/78 was very mild and that pansies were flowering on the 2nd of February 1478. Similarly, in the chronicle by canon Gilles Jamsin at Liège, Belgium, also 1478, he recorded that on the 5th of February white roses were in bloom. On the 28th of April he picked ripe strawberries, on the 4th of May there were ripe cherries on the market and on the 29th of that month the lilies flowered and he ate fructus pisorum (sugar peas). These records probably derive from plants growing in convent gardens, but may also hold for the plants grown in the spring of 1478 in gardens of the common man.

Many archival records report cabbages, leek and onion and a few other vegetables for the Netherlands (SANGERS 1952, 1953). These crops must have been grown in vegetable gardens, but in these records such gardens are not described and rarely mentioned. With high prices of building land as in Amsterdam, most land had to be used for buildings. In the back yards and gardens second houses ('achterhuizen') were erected and in such towns the houses lost their gardens. However, small nooks will have been saved as long as possible to grow herbs and a few ornamentals (ROEVER 1992, SCHELLER 1992). But this is not the case for less crowded towns. Here the yards and gardens were used for vegetables, and second purposes (for instance baking houses, loos, horse stables, pigties and chicken pens). When there was still some space left one or more fruit trees were grown (MEISCHKE 1980). Also, cow stables, vineyards and haystacks could be found (HENNEBO 1962, OERLE 1975). Some towns such as Wageningen (Fig. 1) had quite some open areas in the 17th century which were used as gardens and even as arable fields. These open areas will have been larger in the Middle Ages. In addition to vegetables, arable crops were grown, whereas several orchards are documented. In Amsterdam, such an orchard was abolished to build the 'New Church' in the 15th century (DUDOK VAN HEEL et al. 1993). Near this area a plum orchard and a vegetable garden with sage, cole crops, leek, onion and garlic occurred in 1421. This garden still existed in 1482, but in 1543 it was used as a yard. Mostly, orchards in town were owned by rich people (ROEVER 1996) and were mostly apple orchards, but pear, plum and cherry orchards did also occur. For instance, the count of Holland must have possessed an orchard in the town of Leyden, as records dated 1363 and 1381 refer to the 'Graven boomgairt' (count's orchard).

Similar developments took place in other towns in Europe. Names of town quarters such as the 'Mennelines Gartden' in Worms, mentioned in 1307, and the 'boumgarten' (orchard) in Augsburg in 1383, both in Germany, conserved the former land use (ENNEN 1978). In Amsterdam the quarter 'Jordaan' might refer to a garden. However, the etymology of the name of this quarter is not known (French: jardin) (VEEN 1998).

A record by the ambassador Ibrahim ibn Ahmed at-Tartoesji travelling to the German Emperor, and passing Mainz in the 10th century, mentions, that he was astonished to see that a part of the town land was used as arable land. He reported: 'she (= Mainz) is rich of wheat, barley, spelt [fields], vineyards and fruit' [orchards] (DROSSAERS 1968).

Fig. 1: A bird's-eye view of a part of the city of Wageningen, the Netherlands
Note the many empty areas, which are vegetable gardens, the orchards, and the haystack. The hay may have come from the grass grown under the orchard trees. Borrowed from SLICHTENHORST (1654)

In several towns quite a number of farmers were living. In this respect we should remember that several towns started as a walled-in farmer's village. Later, these farmers could organise themselves in guilds. Hence, we find records in Nijmegen of a 'boulude' (farmer's) guild and in Maastricht of an 'ooftmengers' (fruit tree growers) guild (ALBERTS 1983). In this town an alderman with the name 'Jan de gherdenere' occurred in 1294 (VENNER 1998). Apparently, the profession of the alderman was gardener. Both towns are in the Netherlands. In Lübeck, a market gardener's guild existed. The members were considered second-class citizens ('Medebörger', i.e. co-citizens); they had to maintain the earthen wall, ramparts and canal, and to clean the city (Busch 1984). This last occupation should have brought in compost for their gardens. In Würzburg, guilds of gardeners ('ortulanorum') existed in 1373 (KITTEL 1970). Lübeck and Würzburg are both in Germany.

Parish priests also maintained gardens, in which they grew vegetables for home consumption and ornamentals to decorate the church (SANECKI 1992).

Poverty of pictures of medieval vegetable gardens

When GOTHEIN (1926) illustrated her chapter on medieval gardens she used a painting of Pieter de Hooch (1629-1683)! She probably did so as she could not find an older picture. Earlier and later crop and art historians studied many medieval paintings and manuscripts (mostly with a religious background) as source of information on many subjects of interest. It appears that these sources document wild and some domesticated ornamental plants, but no agricultural crops and vegetables (VAN KREVELEN 1977, ZEVEN and STEMERDING 1986). Any depicted garden is that of a castle, a monastery, an abbey or a hospital. Further, we may find pictures showing activities of farmers on the field, for instance harvesting a cereal crop, but it is impossible to say whether it is wheat, barley or rye. Also garden activities are depicted as digging, planting, grafting and pruning. But whether after the digging a vegeta-

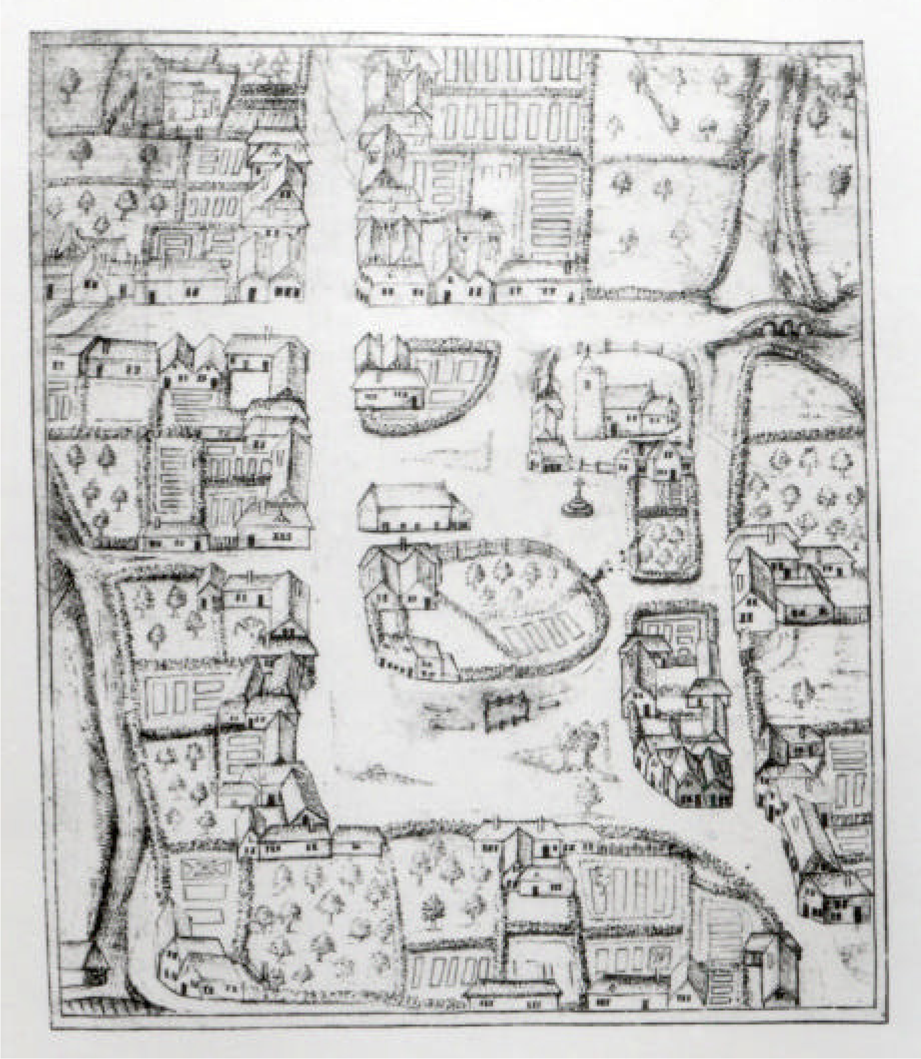

Fig. 2.: A plan of Wilton, Great Britain, ca 1565
Note the gardens and orchards scattered about. Borrowed from LANDSBERG (1995)

ble garden was established is not shown (ZEVEN 1993, 1994). Up to now we have not found for northwest Europe a picture of a medieval vegetable garden of the common man. As GOTHEIN in 1926 we still have to use for northwest Europe post-medieval illustrations.

The town plans, made by Jacob van Deventer for the Habsburg king Philips II around 1570, are important sources for the Netherlands and adjacent areas. As already illustrated above (Fig. 1), the plan of Wageningen drawn in a bird's-eye view in ca 1640, shows many gardens. These will have been vegetable gardens. The first two documented true ornamental gardens date from the 19th century (ZEVEN 2001).

Similarly, for many other towns vegetable gardens occurred within and outside the town walls. An example is given by WILLERDING (1987), who showed that between the inner and the outer walls of the town of Göttingen, Germany, vegetable gardens were established.

Figs. 3 (top) and 4 (right, detail of Fig. 3):
The Census at Bethlehem, painted by Pieter Brueghel (Museums van Schone Kunsten, Brussels, 1566
A cabbage garden is located at the right hand side in front of the bended person. At the left-centre side at the river bank we see cut stems. They could be left of cut coppice or of cabbage plants. Borrowed from Marijnissen (1969)

Two other examples are presented by LANDSBERG (1995), who depicted bird's-eye view plans of two villages in Great Britain (as example Fig. 2).

Further, some cabbage gardens were painted by Pieter Brueghel. In the painting The Census at Bethlehem (Museums van Schone Kunsten, Brussels, 1566) two small gardens are depicted: one with plants of the palm-kale, covered by snow, the other with the left stems of a harvested cabbage plot (Figs. 3 and 4). In the painting The Building of the Tower of Babel (Kunsthistorisches Museum, Vienna, year?) there is also a small cabbage plot (Figs. 5 and 6).
Similar bird's-eye view plans of ca 1640 as those of Wageningen, quite a number of or-

Figs. 5 (top) and 6 (right, detail of Fig. 5): The Building of the Tower of Babel, by Pieter van Brueghel (Kunsthistorisches Museum, Vienna, year?)
The house with the cabbage garden is located behind the wall at left-centre

chards are depicted. Such orchards may indicate that they also existed in the Middle Ages.

Conclusions

In archival documents dating back to the Middle Ages, mention is made of the sale of a house, its yard and its garden. This garden will have been a garden where herbs and vegetables and a few fruit trees were grown. If the garden was large also arable crops may have been cultivated, and orchards established. In spite of their common and wide distribution, the vegetable gardens of the medieval common men have not been depicted and described in northwest Europe. In sales documents orchards may be mentioned because of a result of the financial value of the trees. However, the number of trees and the fruit crop is often not mentioned.

Exchange of material and knowledge will have taken place between common men and gardeners of monasteries, abbeys, castles, mansions and hospitals.

Actually, not much has changed: the vegetable gardens of the present-day common men, although as in the Middle Ages, widely occurring, are still rarely depicted and described. They are too ‘common’, too ‘vulgar’.

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Paintings from the 16th to 18th centuries by Flemish and North-Netherlands artists as a source for investigating the evolution of vegetables: a summary

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Abstract

Our domesticated, i.e., cultivated crops originated from wild plants. During their domestication some plants changed little and others to a great extent. The whole plant or a part of it may change in various characters such as shape and colour.

For most crops we know how their wild ancestors look like, and we also know the appearance of the present-day crops. But how did these crops look like in the 16th-18th centuries? Paintings, made during these centuries, may give an answer to this question. Our investigations were restricted to paintings made in Flanders and North-Netherlands (present-day Netherlands).

Some results

- Many forms of our crops of the 16th-18th centuries can easily be identified as their appearance is similar or even identical to the present-day forms.
- The colours of carrots on the investigated paintings are orange, yellow, white, red and purple. The orange type has become, nowadays, the main type for human consumption, whereas this type together with the other colour types are being used for fodder.
- The paintings show the presence of red and purple cabbages. In the beginning of the 20th century the red types were still offered on the vegetable markets at Amsterdam and probably also elsewhere. They were disliked and therefore cheaper.
- Some paintings show red (= purple) cabbage covered by a silvery gloss of unknown cause.

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Fig. 1: Market scene, by Jean Baptist Saive, Namur 1540-Malines 1624. Private collection

- Three paintings, made in Flanders, show savoy cabbage with a yellowish heart, whereas paintings from North-Netherlands do not show this colour type. This difference may indicate that the savoy cabbage with a yellowish heart only occurred in 17th-century Flanders.
- After harvest of cabbage and cauliflower the stems remained on the field. So paintings do not show the length of these stems. Only one painting depicts cauliflowers with stems of some 30 cm.
- Several shapes of the roots of turnips occurred.
- On the continent turnips are white, whereas in England the consumer demands brownish ones. This difference helps in identifying the country where a painting with turnips has been made.

- Many fruits are depicted. They may have been harvested from single standing volunteer trees, which remained after negative mass selection (man will have removed 'disliked' trees) or from orchards with grafts after positive mass selection (obtained from 'liked' trees).
- Bearded and beardless wheat ears have been painted. The latter type look similar to those of the landrace 'Zeeuwse Witte' (Zeeland White).
- Although kale has been depicted and described in herbals this crop is not painted. I have no explanation for this.
- Jan van de Groen described in the 17th century in his book De Hovenier, six types of lettuce. On paintings we find only two types. This author described only one carrot form, whereas on paintings several are depicted. This indicates that paintings and early descriptions complement each other.

Final conclusion

Paintings with vegetables, some arable crops and many ornamental plants depicted, form a rich source for the study of the evolution of cultivated crops.

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Sugar beets and related wild species – from collecting to utilisation

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Abstract

During the past two decades the interest in collecting and safeguarding *Beta* germplasm has increased continuously. A new taxonomic system accepted by the largest user group, the World *Beta* Network, is reported and commented here. Aspects of *ex situ* management of *Beta* germplasm holdings are described and the threat of genetic erosion in *Beta ex situ* as well as *in situ* is discussed. The establishment and improvement of information systems and a core collection for *Beta* facilitate users' access to collections, today. Since mid of the 1980s researchers are screening collections mainly in order to detect disease resistance. The total amount of disease evaluation data recorded by GRIN and the IDBB is close to 7,400 data. Useful accessions have been found and resistance traits are being introgressed or incorporated into the sugar beet breeding pool.

Introduction

Cultivated beets are used for vegetable (leaf, petiole, root), forage and sugar production. With a total world-wide production area of 6.96 million hectare in 1998 (HOLTSCHULTE 2000), the sugar beet is the most important crop amongst the cultivated forms. Many beet pests and diseases are known (ANONYMOUS 1995); one of the most important sugar beet disease is the leaf spot (*Cercospora beticola*) affecting more than a third of all sugar beet fields world-wide (HOLTSCHULTE 2000). It can easily be understood that the development and continued improvement of resistant cultivars is of great importance to all sugar beet producing countries. The growing demand for an environmentally sound agricultural production also promoted the search for accessions with novel genes for disease resistance.

In addition to disease resistance, tolerance to abiotic stress receives increasing attention. On the background of the forecasted global climatic change it seems to be prudent to start screening for drought tolerance in *Beta* already today. Higher tolerance to salt stress plays a role in arid production areas. In particular wild beets growing along the sea shores are known for their natural salt tolerance. Research

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institutes in Arabian countries have therefore started investigating the potential of beets for forage production on saline soils. If indeed beets will once be cultivated in Kuwait and similar areas, breeders may face new challenges and will need novel genetic variation to cope with it. Useful genetic variation occurs in almost all of the species and subspecific ranks of the genus *Beta* (GEYT et al. 1990). There are accordingly pragmatic (agriculture) and political (biodiversity convention) reasons to collect and manage genetic resources of the genus *Beta*. This paper deals with taxonomic problems and aspects of collecting, management and utilisation of *Beta* germplasm.

Taxonomy

Though there is a long history of taxonomic research in *Beta*, no fully consolidated taxonomy of the genus exists. Before 1999, collectors of *Beta* germplasm had to deal with unsettled taxonomic problems as it is expressed by the 142 synonyms listed by the Mansfeld database (http://mansfeld.ipk-gatersleben.de/mansfeld/), until two revisions, namely that of *Beta* section *Corollinae* (BUTTLER 1977) and of *Beta* section *Beta* (LETSCHERT 1993) were published. Both contributions improved our knowledge of the taxonomic structure of the genus. BUTTLER (1977) published the correct names of the four sections as shown in Table 1. *Beta* section *Beta* is composed of three species: *B. vulgaris, B. macrocarpa* and *B. patula*. *B. vulgaris* is further divided into two wild subspecies and the cultivated subsp. *vulgaris* with its four cultivar-groups (LETSCHERT 1993, LANGE et al. 1999). LANGE et al. (1999) argued that none of the morphological or cytological characters are suited to unambiguously delineate taxa within the cultivated beet. All characters used by HELM (1957) to distinguish 19 different types of cultivated taxa are subject to continuous variation and will not allow to clearly discern cultivated forms. LANGE et al. (1998), therefore, suggested to apply an open classification system as proposed by HETTERSCHEID et al. (1996). The introduction of the "culton" as taxonomic entity for cultivated beets allowed the formation of large and unambiguous cultivar-groups which can be internationally understood and can be easily handled by users of germplasm who are not familiar with the International Code of Botanical Nomenclature (ICBN) and Latin names. Consequently, the World *Beta* Network (WBN) recommended the use of the nomenclature as shown in Table 1. The introduction of cultivar-groups has simplified the nomenclature and is welcomed as a useful pragmatic approach by beet breeders and other scientists dealing with applied research.

However, there are also disadvantages. A taxonomic name like "*Beta* L. *vulgaris* subsp. *vulgaris* convar. *vulgaris* provar. *flavescens* Lam. and DC. f. *rhodopleura* (Alef.) Helm" readily transfers the information that this germplasm is a red coloured leaf beet with broad petioles. With the replacement of this name by the culton "Leaf Beet Group" this descriptive information linked with the name is lost unless data on petiole width, length, colour etc. have been recorded in an evaluation database. As

HYPERLINK**Tab.1: Taxonomy of the genus *Beta***

Primary genepool	**Section *Beta* (syn. *Vulgares* Ulbrich)** *B. vulgaris* L. subsp. *vulgaris* (cultivated beets) Leaf Beet Group Garden Beet Group Fodder Beet Group Sugar Beet Group subsp. *maritima* (L.) Arcang. subsp. *adanensis* (Pamuk.) Ford-Lloyd and Will. *B. macrocarpa* Guss. *B. patula* Ait.
Secondary genepool	**Section *Corollinae* Ulbrich** • Base species *B. corolliflora* Zosimovich *B. macrorhiza* Steven *B. lomatogona* Fisch. and Meyer • Hybrid species *B. intermedia* Bunge *B. trigyna* Waldst. and Kit. **Section *Nanae* Ulbrich** ***B. nana* Boiss. *and* Heldr*.***
Tertiary genepool	**Section *Procumbentes* Ulbrich (syn. *Patellares*)** *B. procumbens* Smith *B. webbiana* Moq. *B. patellaris* Moq.

long as descriptive databases are incomplete it is essential to document the synonyms of accepted names in parallel.

Lange et al. (1999) mentioned another problem. Letschert (1993) treated wild species of section *Beta*, only, and explicitly did not deal with the weedy and cultivated material. As a result, there is no formal link between the wild and cultivated classification system and no possibility to classify weedy types. It is therefore difficult to develop a determination key for the whole genus as noticed by Frese et al. (2001). In addition to taxonomic problems of *Beta* section *Beta*, more research is required to consolidate the taxonomy of section *Corollinae*. Buttler (1977) in his thorough revision of section *Corollinae* could not deal with the hybrid complex in detail nor could he validate the existence of a *B. foliosa* in Turkey. Section *Procumbentes* might also need a revision since there are indications that *B. webbiana* and *B. procumbens* are closely related if not even identical species (Wagner et al. 1989). Furthermore, there are reasons to assume that the section *Procumbentes* does not at all belong to the genus *Beta* but to a separate genus (WILLIAMS et al. 1976, JUNG et al. 1993). Nevertheless, major users of germplasm holdings are satisfied with the taxonomic system presented in Table 1 as it transfers all the information they need.

Inventory and collecting

The wild species of the genus *Beta* are native to Europe and adjacent areas. The section *Beta* is mainly distributed along the shores of the Mediterranean basin and along the Atlantic coast from the Canary Islands as the most southern outpost to the South of Sweden. Section *Corollinae* frequently occurs in Turkey and the adjacent Caucasus region with outposts in Daghestan and the Talysch mountain (Iran/ Azerbaijan). The only species of section *Nanae* is endemic in Greece where it grows in mountainous areas at elevations higher that 1800 m. Section *Procumbentes* has its major distribution area on the Canary Islands but can also be found in Southeast Spain and along the coast of Morocco where it is rare. Even wider distribution areas have cultivated forms. Where soil, water and temperature allow sugar beet is grown in almost every country of the northern hemisphere as well as in Chile. A similar large distribution area is known for the Leaf Beet Group which is adapted to a very broad range of growing conditions in Europe, Northern Africa, the Americas and in particular countries of the Asian region.

In 1979 the first *Beta* germplasm collecting mission was funded by IPGRI and a number of additional missions followed with the objective to sample wild beets and landraces in the Mediterranean area. Between 1980 and 1990, large geographic gaps were closed by IPGRI and USDA/ARS funded missions (South Italy, Southern part of France, West Atlantic coast, British Islands, Ireland and Denmark) (DONEY et al. 1995) and the collecting data were entered into national databases. On the initiative of the ECP/GR programme, a European inventory of *Beta* collections was established in 1987, and in view of the effective collaboration achieved with the NPGS (USA) it was recommended to assume an international role. The International Database for *Beta* (FRESE and HINTUM 1989) contains information provided by 28 germplasm holdings in 24 countries. This central crop database currently stores passport data on 2,324 sugar beet, 863 fodder beet, 892 garden beet, 631 leaf beet and 4,022 wild beet accessions. The geographic coordinates of collecting sites were used for plotting distribution maps to visualise smaller geographic gaps in the world holding. Subsequently the German-Dutch Cooperation on *Beta* Genetic Resources (Iberian peninsula, East Caucasus region), the Turkish genebank (explorations within the country) and the Polish Gene Bank (landraces in Southeast Poland and adjacent areas) (DALKE et al. 2000) organised collecting trips to purposefully complete the world holding. Today, for wild beets only smaller geographic gaps need to be closed in Europe such as for *B. vulgaris* subsp. *maritima* in Northwest Spain. In countries like

China, India as well as Central and West Asian countries interesting distinct landraces may still exist but these countries are difficult to access either because of their sheer size (China - leaf beet landraces) and/or political reasons (India, Pakistan, Afghanistan).

The main promoters of *Beta* collecting missions (IPGRI, USDA/ARS, German-Dutch cooperation, Turkish genebank) began to change the objectives of collecting trips from capturing useful genetic variations to monitoring and *in situ* management of *Beta* genetic resources. There are indications that species like *B. macrocarpa* (Portugal and Spain), *B. macrorhiza* (East Caucasus), *B. lomatogona* and *B. vulgaris* subsp. (Azerbaijan, inland wild type) are threatened by genetic erosion. To prevent discontinuation of the evolutionary processes in these species, the WBN recommended assessing the threat of genetic erosion case wise and to promote and establish *in situ* management programmes for the extant populations in the relevant areas. In particular, wild species of the sections *Nanae* and *Corollinae* are not adapted to the climatic conditions of Northwest German lowland. They are subjected to a very strong selection pressure towards adaptation to “genebank seed production procedures”. Loss of genetic variation in *ex situ* collections as well as a lack of precise information on the magnitude of genetic erosion within natural growing sites underlines the urgent need for *in situ* monitoring projects.

Maintenance

Beta germplasm collections consist of species and populations with a remarkable diversity of breeding systems and survival strategies (annuality, seed dormancy, seed hardiness, frost resistance, variation for day length reaction and cold requirement). Parts of the section *Beta* germplasm does not at all require vernalisation and starts bolting only 40 days after sowing like *B. vulgaris* subsp. *adanensis* while accessions from Ireland bolt incompletely even after a prolonged vernalisation period. The timely induction of bolting and flowering is only one of the technical management aspects *ex situ* managers of *Beta* collections have to consider. The WBN recommended compiling a seed production manual that is available at the BAZ Gene Bank since 1996. The manual describes experiences made at the location of the BAZ Gene Bank and is valid for this location, only. Some of the experiences are summarised in Table 2. At the BAZ Gene Bank young plants are produced routinely during autumn, winter and early spring depending on the type of germplasm and vernalised artificially if required. The information given below refers to that cultivation method.

Tab. 2: Breeding system and seed yield

Botanical name	Seed type	Prevailing breeding system*	Days from sowing to flowering	Average single plant seed yield in gr. (min–max)
B. vulgaris Leaf Beet Group	Normal	Outcrossing	up to 180	70 (15-170)
B. vulgaris Garden Beet Group	Normal	Outcrossing	up to 180	40 (15-70)
B. vulgaris Fodder Beet Group	Normal	Outcrossing	180	50 (15-70)
B. vulgaris Sugar Beet Group	Normal	Outcrossing	180	50 (15-70)
B. *vulgaris* subsp. *maritima*	Varying degrees of dormancy	Outcrossing	40-260	30 (4-110)
B. vulgaris subsp. *adanensis*	Varying degrees of dormancy	Inbreeding	40-60	20 (13-75)
B. macrocarpa	Varying degrees of dormancy	Inbreeding	40-60	20 (8-57)
B. patula	Normal	No records	40-60	12
B. corolliflora	Hard pericarp	Outcrossing	430	30 (25-50)
B. macrorhiza	Hard pericarp	Outcrossing	420	10 (1-21)
B. lomatogona	Hard pericarp	Outcrossing	450	5 (1-26)
B. intermedia	Hard pericarp	Apomictic	450	20 (15-25)
B. trigyna	Hard pericarp	Apomictic	430	30 (25-50)
B. nana	Hard pericarp	No records	No records	No records
B. procumbens	Hard pericarp	Outcrossing	60	20 (2-80)
B. webbiana	Hard pericarp	Outcrossing	60	20 (2-80)
B. patellaris	Hard pericarp	Inbreeding	60	20 (2-80)

*according to JASSEM (1992) and own observations

Access to collections

Users mainly search for *Beta* accessions in two databases: the International Database for *Beta* (IDBB) (http://www.genres.de/beta/) and in the Genetic Resources Information Network (GRIN) of the National Plant Germplasm System of the USA (NPGS) (http://www.ars-grin.gov/npgs/). The latter combines passport, characterisa-

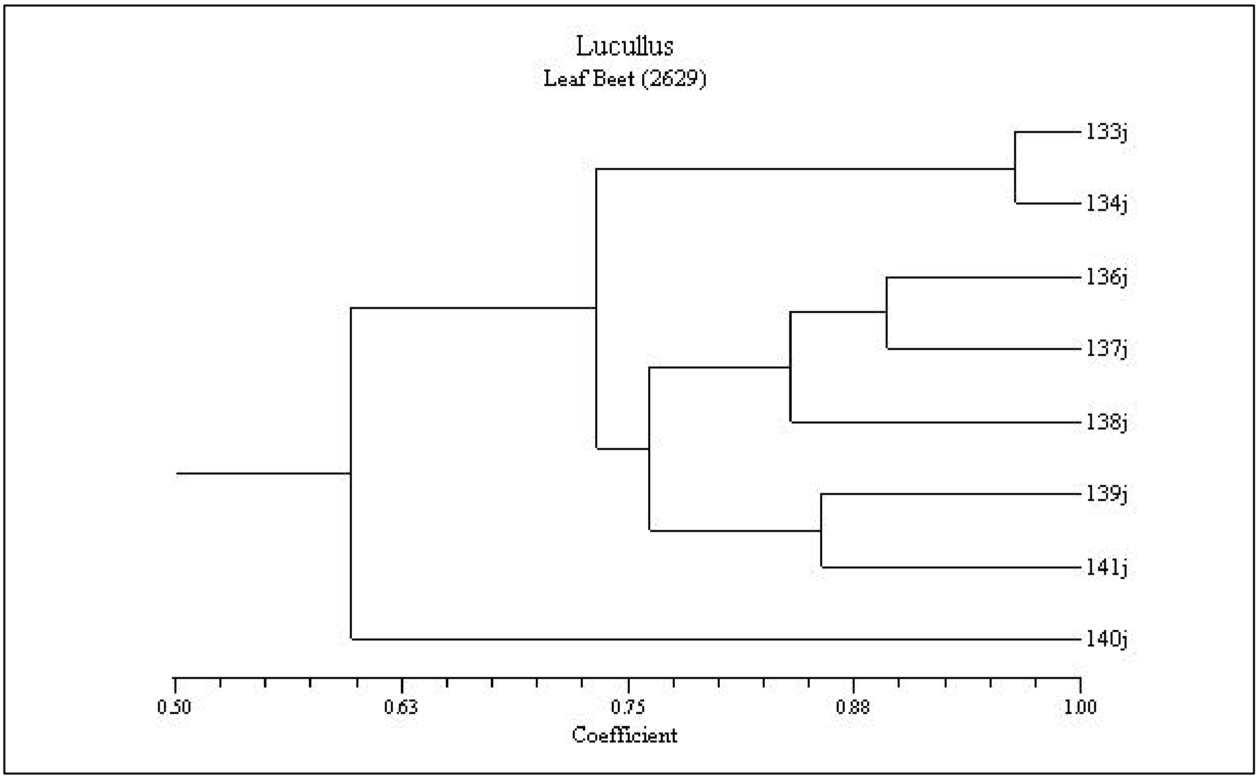

Fig. 1: Genetic similarity within a group of probable duplicates estimated by AFLP markers
The IDBB2629 points to the most original sample (MOS) as recorded in the IDBB (FORD-LLOYD et al. 2001)

tion and evaluation data as well as narratives, pictures and mapped collection sites of individual accessions.

The IDBB provides passport data online via ZADI/IBV and more recently a downloadable IDBB module containing evaluation data and passport data linked with them (http://www.fal.de/bgrc/eu9542).

The access to useful accessions can be facilitated by rationalising collections and by creating core collections. It is generally assumed that germplasm holdings contain too much redundant material that decreases the chance of detecting useful genes in unique accessions hidden in the bulk. Within the EU project “Evaluation and enhancement of *Beta* collection for extensification of agriculture – GENRES CT95-42)” probable duplicates have been determined in the world *Beta* holding based on similar sounding names (FRESE and HINTUM 1989). In total 350 accessions sorted into duplicate groups were ordered from partner genebanks, grown in the field for visual inspection and morphological comparison. A second seed lot of each was sent to the University of Birmingham, School of Bioscience, where AFLP and SSR analysis were undertaken to estimate the genetic similarity between accessions within a group of probable duplicates. The preliminary results indicate that there are less duplicates than expected. The results also indicate a curator's decision problem. There are, for example, entries in the duplicate group 'Lucullus" (most original sample IDBB2629) that are similar at a 90% level (entry 133 and 134) while others (entry 140) are rather distinct (Fig. 1) (FORD-LLOYD 2000, FORD-LLOYD et al. 2001).

Whether entry 134 can be considered as redundant material that should be combined with 133 under the assumption that both accessions contain the same useful genetic variation still is at the curator's discretion.

To avoid unintentional screening of duplicates, a core collection of the "most original accessions" has been created using taxonomic and geographic data documented in the IDBB as well as curator's knowledge (FRESE 2000). Between 600 and 800 accessions of this core collection have been screened for resistance to eight diseases as well as for drought tolerance. The data set emerging from the EU project GENRES CT95-42, including AFLP and SSR data derived from the duplicate search subproject, will be used to review and improve the currently rather large core collection set.

Tapping the genepool

In 1993 the World *Beta* Network (WBN) recommended to increase evaluation activities in vegetable beets (Leaf Beet and Garden Beet Group). A comprehensive evaluation of a Garden Beet Group collection was conducted by BARANSKI et al. (2001) a few years later. Amongst others, a wide variation for nitrate content (384 – 2894 mg/kg FM) was detected (GRZEBELUS and BARANSKI 2001). Low nitrate content is a quality character for red beet juice marketed as health product. However, such evaluation projects are still an exception.

There are actually only two major evaluation activities. A programme for systematic screening has been set up by the USDA/ARS which is run by the Crop Germplasm Committee with great success since 1987 (DONEY 1998). Many of the new disease resistances used today in breeding were first detected in the USA such as the rhizomania resistance (WHITNEY 1989). The individual sets of accessions vary between 30-60 to limit the yearly workload of participating institutions and the required funds. The strength of the programme lies in its continuity both in terms of funding and expertise.

Within the European Union or individual member states no such programme exists for *Beta*. The council regulation 1467/94 through which the GENRES CT95-42 is being funded must therefore be considered as a unique chance for germplasm enhancement of cultivated beets. Between 1996 and 2001, the *Beta* core collection has

Tab. 3: Number of evaluation data points in two information systems

Trait	IDBB/GENRES	GRIN/USDA-ARS
Virus diseases	1989	1039
Bacterial diseases		221
Fungal diseases	2044	1527
Pests		533
Total	4033	3320

been screened by five project partners for the following traits: *Rhizoctonia solani*, *Aphanomyces cochlioides, Pythium ultimum*, yellowing viruses (BMYV, BYV), *Cercospora beticola, Erysiphe betae*, rhizomania (BNYVV) and drought tolerance. The numbers of evaluation data points generated by this project are summarised in Table 3. The amount of disease resistance data is higher in Europe as compared to data contained in the Genetic Resources Information Network (GRIN), while the number of distinct disease and pest agents is larger in the USA.

Disease resistances are not very frequent. The following estimates were calculated based on the data contained in the IDBB (number of accessions with a score <2 compared to the total evaluated number): Resistance to fungal and virus diseases occur in *B. vulgaris* subsp. *maritima* at a frequency of 2.1%, in the Leaf Beet Group (2.8%), in *B. corolliflora* (3.8%) and in *B. patellaris* (3.7%). For individual disease agents (Beet Mild Yellowing Virus), the frequency of resistant material can be much higher (7.5% of 550 accessions tested) (ASHER and LUTERBACHER 2001).

Beets are mainly outcrossing. It is therefore essential to determine the within-population variation. BÜTTNER et al. (1997), when investigating a set of *B. vulgaris* subsp. *maritima* accessions single plant wise, noticed variation for rhizomania resistance in the accession BGRC54817. The simply inherited rhizomania resistance was fixed in a donor line through selection and inbreeding. S_2 lines are available today for introgression of this resistance trait into the sugar beet breeding pool.

Compared to breeding for *C. beticola* resistance, the utilisation of rhizomania-resistant genebank material has been straightforward. Breeders had to chose a different, long-term crop enhancement and genetic resources management strategy for the leaf spot resistance. Just in the case of this economically very important character, breeders are struggling hard to improve the resistance level. The resistance is inherited by at least three to five QTLs (SCHÄFER-PREGL et al. 1999). Accessions showing variation originate from very different collecting sites. Some of these accessions may contain minor genes that are not shared by all wild beet (*B. vulgaris* subsp. maritima) populations in common. Following the “buffer population” breeding scheme developed by the French company Florimond Desprez, accessions showing variation for resistance are crossed to a monogerm, self-fertile sugar beet population that segregates for genic male sterility (so-called Doggett population). The breeding scheme ensures maintenance of 50% wild genome in the F1 to F3 or further generations and allows a maximum recombination between the sugar beet and wild beet genome. It is assumed that novel genes for *C. beticola* resistance will be incorporated into the sugar beet breeding pool enabling future breeding progress (FRESE et al. 2001). Because of the difficulties of all sugar beet breeders regarding the development of highly leaf spot resistant cultivars, and the economic risks connected with a long-term utilisation strategy, collaboration between companies in Europe appeared to be advantageous. This joint breeding effort is currently co-ordinated through the Study Group Breeding and Genetics of the International Institute for Sugar Beet Research (IIRB).

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Utilisation of plant genetic resources for valuable raw materials in foods, cosmetics, and pharmaceutical products

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Abstract

Plant raw materials are used in a wide range of products such as phyto-pharmaceuticals, soaps, perfume oils, cosmetics, alcoholic and non-alcoholic beverages, ice-cream, convenience foods and others. This paper presents a short survey of those natural raw materials, which are most relevant today for industrial production. In this context some information is provided concerning the application, the effectiveness, the importance on the market and the analysis of the individual valuable substances.

Introduction

There is a growing interest in the pharmaceutical and cosmetic industry to use medicinal plant extracts for various fields of applications. Health food shops and pharmacies present numerous phyto-pharmaceuticals claimed to benefit a wide range of conditions. Presently, there are also some attempts to introduce new products, so-called “nutraceuticals” and “cosmeceuticals” which can be defined as food and cosmetic products that result in the delivery of a specific health benefit of improvement.

Since the addition of synthetic antioxidants to foods or cosmetic materials is very limited for legislative reasons, natural antioxidants such as vitamin C, vitamin E, distinctive flavonoids or carnosic acid are commonly used for that purpose. In recent years also the use of natural dyes has regained some importance especially in beverages and cosmetics.

Natural aroma compounds

Intensive research activities over the past 40 years have identified more than 10,000 volatile flavour compounds in nature that are able to trigger specific association of food materials in the receptors of the human brain. These aroma complexes or iso-

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Tab. 1: Occurrence of flavour substances in various fresh fruits and processed foods

species	total volatile flavour substances [mg/kg]	number of volatile flavour compounds
Banana (raw)	12 – 18	150
Raspberry (raw)	2 – 5	150
Strawberry (raw)	2 – 8	150
Tomato (raw)	3 – 5	250 – 300
Hazelnut	40 – 50	250
Coffee (roasted)	100	800 – 1000
Cocoa (fermented)	100	500 – 700

lated substances are used for the compounding of natural flavourings but they may be also starting materials for chemical or biochemical syntheses in the flavour industry.

Generally, the concentration of the individual flavour substances is comparatively low. Table 1 demonstrates the concentration of the total amount of flavour compounds in some selected fresh and processed plant materials.

As can be seen from this table, the raw fruits contain relatively low concentrations of volatile flavour substances while foods that have been subjected to a heating process (such as roasting or fermentation) tend to present somewhat higher amounts. Furthermore, the number of flavour compounds increases during processing; the leader here is probably freshly roasted coffee.

Use in cosmetic products

According to their major active principles, plant extracts used in cosmetic products can be subdivided into the following main groups:

- Essential oil plants
- Flavonoid drugs (extracts with anti-inflammatory activity and healing properties, extracts which stimulate the capillary blood pressure)
- Tanniferous plant extracts or those containing silicic acid
- Saponin extracts

- Sedative or stimulating plant extracts
- Extracts used as additives for sun protection

Most of the drugs with dermatological use belong to the group possessing anti-inflammatory activity; some of these species are listed in Tab. 2. Another group with a similar high importance consists of drugs presenting predominantly wound-healing properties (Tab. 3).

Most of the drugs mentioned here are already registered and recommended by the German Institute for Pharmaceutical and Medicinal Products in its positive monographs for the supplementary treatment of skin ailments and wounds, the so-called Commission E.

Tab. 2: Drugs possessing anti-inflammatory activity

species	plant component	application/effectiveness
Juglans regia	leaves, fruit peels	dermatitis, ulceration
Avena sativa	herb	skin disease
Quercus robur	bark	slight skin inflammations
Arnica montana	flowers	furunculosis
Chamomilla recutita	flowers	surface-phlebitis
Hamamelis virgiana	flowers/bark	astringent, hemostatic
Plantago lanceolata	herb	inflammatory skin diseases, antibacterial, astringent

Tab. 3: Drugs possessing wound-healing properties

species	plant component	application/effectiveness
Echinacea purpurea	herb	wounds closing up very slowly
Equisetum arvense	herb	improvement of wound healing
Calendula officinalis	flowers	improvement of wound healing
Hypericum perforatum	herb	first degree burns
Chamomilla recutita	flowers	lesions of skin surface
Populus species	leaves/stems	lesions of skin surface, sunburn
Capsella bursa pastoris	herb	bleeding skin lesions

During the recent years, rosemary extracts with high percentages of carnosic acid and pure rosemaric acid are increasingly used for cosmetics because of their multifunctional effects. Beside antioxidative, antimicrobial and antiphlogistic properties also an improvement of the membrane stability could be demonstrated in various cosmetic formulations. More than the European native plants, rather the exotic species such as *Aloe vera* and green tea are currently playing a leading role in the trend. It has been found that polyphenols occurring in green tea extracts protect the skin from free radicals and possess antibacterial and anti-inflammatory effects. According to the latest findings, also extracts made from the South African rooibos (*Aspalathus linearis*) have antimutagenic, anti-carcinogenic and anti-inflammatory properties. The antioxidant activity is mainly related to the flavonoids, especially both aspalathin and nothofagin which cause an acceleration of the healing process in various skin diseases such as eczema or sun burn. Because of these activities, rooibos extracts are used in South Africa especially in baby products in the form of creams or soaps. Furthermore, it has been observed that the flavonoid quercetin blocks the histamine release from the mast cells and so it reduces allergic reaction in man.

Cultivation and production of essential oils

In the first half of the 19th century, the production of essential oils was industrialised due to the increased demand for these raw materials as perfume or flavour ingredients. Companies such as Schimmel and Co. in Miltitz near the city of Leipzig were founded at this time (GILDEMEISTER and HOFFMANN 1916). In the 19th century, Leipzig was a centre for the production of essential oils and other plant extracts derived from ginger, cinnamon, sandalwood as well as chamomile and lavender. Around the town of Leipzig, roses and other important fragrance plants were cultivated on large fields. The majority of essential oils are mixtures of various mono- and sesquiterpenoids. Besides, also many other aromatic substances exist, including phenols. The amount and composition of essential oils may also vary with the time of harvesting and with the applied distillation process.

Liverworts are rich sources of terpenoids and phenolic compounds, and many of them show interesting pharmacological activity. But the great majority of commercially available essential oils is produced from seed plants (MERKEL 1972, RASSMANN 1989, HEGNAUER 1978).

Agrumen or citrus oils are obtained from leaves, blossoms, fruits or fruit peels of various citrus species. Usually the oils of orange, grapefruit, mandarin, lemon and lime are obtained by pressure from the fruits and fruit peels. So-called “Petitgrain oil” is produced from nearly all citrus species but predominantly from leaves and twigs of bitter orange trees. Neroli oil is obtained by steam distillation of the blossoms of the bitter orange tree. Main components responsible for the characteristic, fresh citrus aspects are limonene, ß-pinene, ?-terpinene, terpinen-4-ol, a-terpineol, and methyl N-methylanthranilate.

Garlic and onion oils are mainly used in seasoning mixtures for the food industry. The oils are produced by steam distillation of the crushed bulbs. The oils have a very strong pungent odour and the main active odour principles are dialkyl- and dialkenyl polysulfides which are enzymatically produced from the cysteine sulfoxides such as alliin occurring in garlic. Leek oil is commercially less important. Also here, specific sulfides and disulfides are responsible for the typical aroma. Due to the very low yield, this oil is very expensive.

Essential oils are also produced from several trees and shrubs such as cedar wood oil, eucalyptus oil, and of course from species of the conifer family. Essential oils produced from grasses such as *Cymbopogon nardus* (citronella oil), *Cymbopogon flexuosus and Cymbopogon citratus* (lemon grass oil), *Cymbopogon martinii* (palmarosa and ginger grass oil), as well as *Vetiveria zizainoides* (vetiver oil) are used either as starting materials for single fragrance and flavour chemicals or as such in various perfume formulations.

A large number of *Mentha* species, subspecies and varieties are used for essential oil production such as peppermint, spearmint, pennyroyal, cornmint and *M. citrata* oil. Among the lavender plants used for cosmetic products, three are particularly important: French lavender (Lavandula angustifolia), spike lavender (L. latifolia) and the hybrid of these two species.

Sage oils are used in fairly large amounts in the fragrance industry, they are obtained predominantly from Salvia sclarea (clary sage), S. officinalis, S. lavandulifolia (so-called Spanish sage oil) and S. triloba (Greek sage oil).

To obtain the essential oils, the crushed plant material is distilled with steam or extracted with a solvent, depending upon the material in question and the desired product. Since many of the valuable plant substances are thermo-labile or sensitive to acids, the composition and quality of the isolated products depends strongly on the individual applied process. In order to minimise the amount of such artefacts, today also supercritical carbon dioxide extraction is used, which possesses very good solubility properties and leave no problematic residues (Ziegler 1982). Furthermore in most cases the resulting products represent a more authentic sensory impression of the extracted plant material.

The production of lavender oil from the wild plant Lavandula angustifolia is closely connected with the city of Grasse, which was the centre of perfume manufacture during the Middle Ages. The collecting of fragrance raw materials such as wild lavender was performed by the peasants who lived in the area of Grasse. At that time many of them bought travelling copper stills to produce the lavender oil directly in the mountains. Today, the main part of lavender oils is made from lavandin which is a hybrid of Lavandula angustifolia and Lavandula latifolia. Lavandin is infertile and is therefore propagated by cuttings (Lawrence 1981).

The essential oil of L. angustifolia has a high linalyl acetate and a relatively low linalool content. In contrast to that, the ester content in spike lavender oil is very low but it contains large amounts of linalool. The ester content of lavandin oil made from the cultivar 'Abrialis' is in between the values of the parent plants but today there exist also other hybrids such as 'Super' or 'Grosso' containing high levels of linalyl acetate.

Utilisation for the production of perfume oils and synthetic fragrances

The estimated annual production of essential oils world-wide is about 45,000 tons. Of these, ca. 70 % are used for the food industry. Especially citrus oils and mint oils have some economic importance in this context because these raw materials are used in large quantities. The world production of perfume oils, for all applications taken together, is about 300,000 tons. It follows therefore that the average proportion of natural products in a perfume formulation is about 4.5 %.

Important fields of applications for essential oils are both in fine perfumes as well as in toiletries such as soaps. Already in classical so-called "Cologne" notes such as "4711 Echt Kölnisch Wasser", which was first created in 1772, bergamot oil was used to obtain the typical fresh character. But also today the special scents of lemon, mandarin, orange and lime are very important for the development of numerous perfumes such as "CK-One" of Calvin Klein or "Cool Water" of Davidoff.

One of the most frequently used essential oil substances in this context is α-pinene occurring in turpentine oil but also in many other essential oils. In can be transformed under acidic conditions into camphene, which in presence of acetic acid forms isobornyl acetate, one of the important items for functional perfumery. Saponification and oxidation of isobornyl acetate give camphor (Fig. 1).

Another synthesis uses solvent extracts of clary sage, which contain sclareol as main component. This diterpene alcohol is used as a starting material for numerous ambra fragrances such as ambrein which is the major component in the secretion of the sperm whale, possibly resulting from a pathological condition. In presence of light and air ambrein is easily oxidised forming dihydro-?-ionone which also presents strong ambra odour (Fig. 2) (BRUNKE 1990).

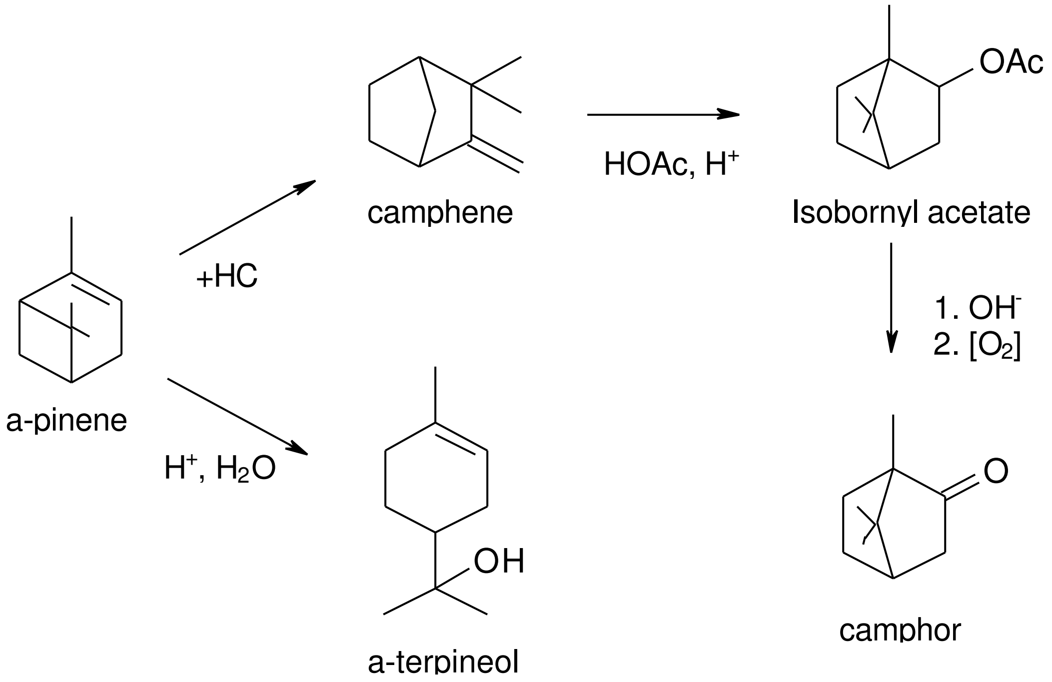

Fig. 1: Synthesis of important basic fragrance materials from a-pinene

Onion and garlic bulbs are very important raw materials and are processed in high amounts into various products in the food and pharmaceutical industry. Onion juice is obtained by repeated expression of the plant tissue and subsequent flash heating up to 160°C and then cooling down to 40°C. The juice contains both flavour and aroma precursors which are mainly cysteine sulfoxides. In order to get a juice concentrate the freshly produced onion juice is carefully evaporated to approx. 75 % solids. Solvent extracts of onions are performed in the flavour industry in order to obtain roast flavours for meat or instant soups. These dark brown juices may be mixed with sugars and amino acids or lecithin to yield an oleoresin having a flavour intensity approx. 100 times that of fresh onions. In the US, also garlic juice has some importance as health product. Last but not least, it has to be mentioned here that numerous garlic preparations are very successful also in the European market (FENWICK and HANLEY 1990).

Analytical characterisation

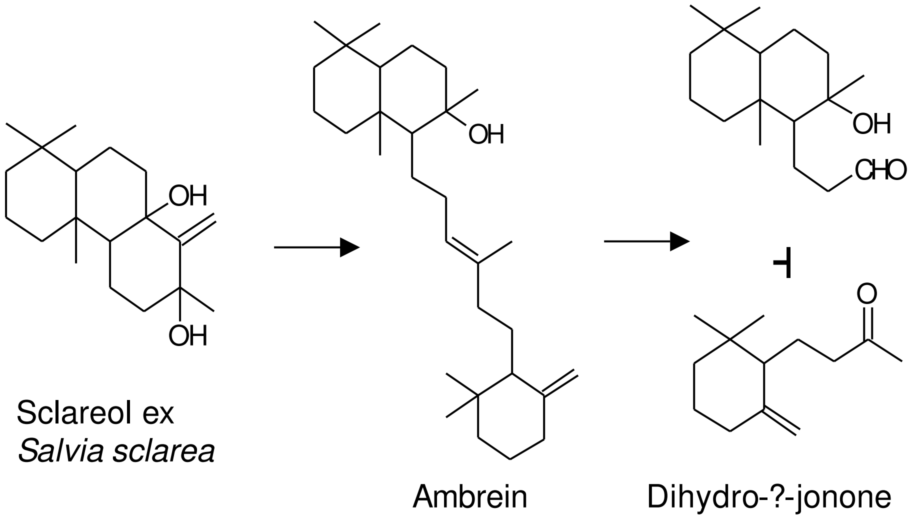

Fig. 2: Formation of ambra fragrance materials from sclareol

For the analytical evaluation of genetic resources, several methods are in use. Volatile components are usually analysed by GC methods (GC-SPME, GC-O, GC-MS, etc.) or by electronic noses, whereas non-volatile components are determined by HPLC methods. But also spectroscopic methods are applied for the rapid and non-destructive measurement of plant constituents, especially in those cases if only small sample amounts are available and if rapid and non-destructive analyses have to be performed. Recently, several applications were described using Near-Infrared Spectroscopy for the prediction of several quality parameters in plants without performing any clean-up procedures. Applying these methods, valuable components such as carnosic acid and various essential oil substances can be simultaneously determined.

Furthermore PCR-based methods are used for DNA-analysis or the detection of specific DNA sequences. But the pre-condition to apply these methods is to exactly know the coding sequences which are responsible for the expression of distinctive parameters. Figure 3 demonstrates the essential oil composition of various chamomile types. For pharmaceutical and cosmetic products, essential oils with the highest a-bisabolol content and a very low content of bisabolol oxides are preferred. As can be seen in the figure, the cultivar ‘Manzana’ with a high a-bisabolol and chamazulene content shows the best match to this specification.

Future activities should focus on the application of efficient analytical tools to screen the genetic resources with regard to valuable substances. As a result of these studies, when the complete data have been evaluated, new interesting compounds will be discovered or suitable plants for cultivation will be found. This will hopefully be the basis for the development of new cultivars with “added values”.

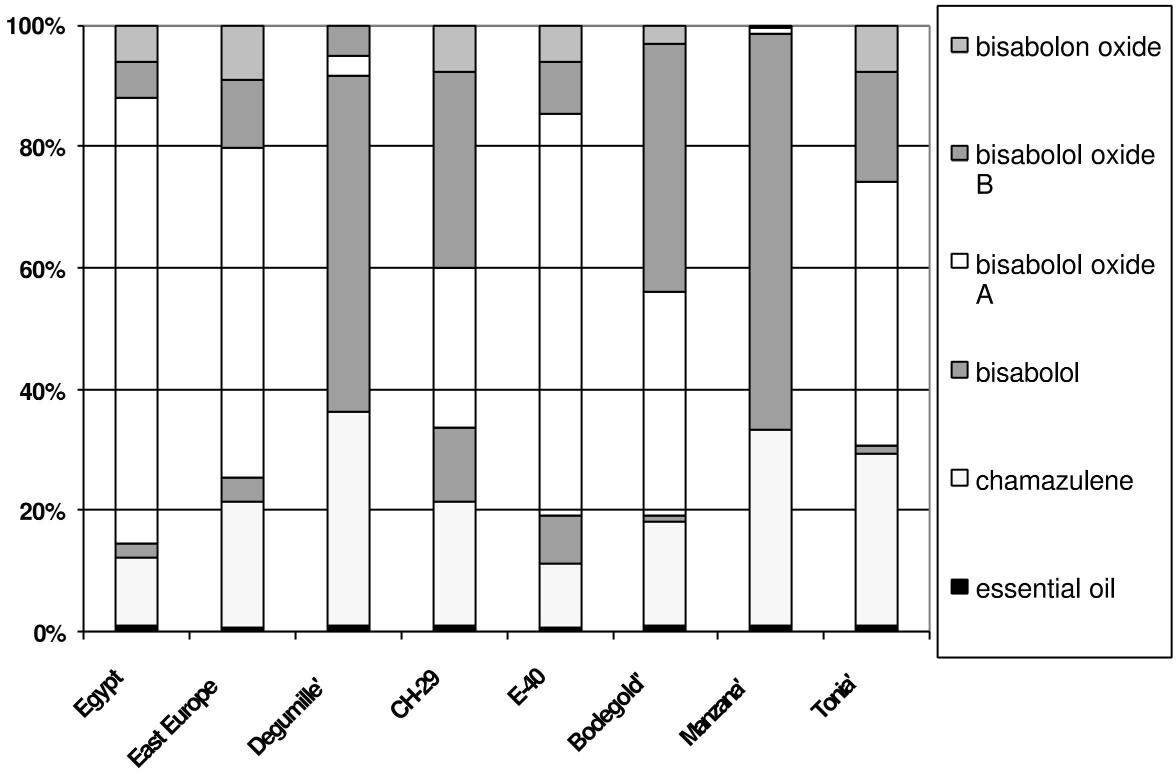

Fig. 3: **Contents and composition of the essential oils of various chamomile cultivars collected at different locations**

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Proof of long-term stored potato germplasm by use of molecular markers

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Abstract

Specific SSRs were successfully used to generate fingerprints of cultivars which have been long-term stored in different genebanks located at Groß Lüsewitz and St. Petersburg. Using twelve pairs of SSR primers it was possible to distinguish all the twelve cultivars used in the present study. By comparison of the banding patterns identity in ten of twelve cultivars of both genebanks was proven. In the cultivars 'Early Rose' and 'Epicure' differences in banding patterns were found for five and ten SSR primer pairs, respectively. Conceivable reasons are discussed.

Introduction

The difficulty in confidently distinguishing cultivars is a problem facing potato breeders, seed growers, micropropagators as well as germplasm curators. Proof of identity of varieties plays an important role in the work with collections in genebanks. Clonal identification in potato has been traditionally based upon morphological criteria. However, limitations exist because this method is time-consuming. Therefore, numerous attempts have been made to develop biochemical and DNA markers which can be utilised in cultivar identification.

Our objective was to determine whether SSRs will generate fingerprints of cultivars and can be used as an efficient and rapid technique for proof of identity of long-term stored material.

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Tab. 1: Comparison of fingerprints of cultivars long-term stored in two different genebanks (+ = identical, - = different, / = not tested)

Cultivar	Origin	Year of Release	Identical or different banding patterns by using SSR primers (No)											
			1	2	3	4	5	7	9	10	12	13	15	16
Desiree	Netherlands	1962	+	+	+	+	+	+	+	+	+	+	+	+
Detskoselskiy	Russia	1959	+	+	+	+	+	+	+	+	+	/	+	+
Dorisa	Germany	1984	+	+	+	+	+	+	/	+	+	+	/	+
Early Rose	USA	1867	+	+	+	+	+	–	–	–	+	–	+	–
Epicure	Great Britain	1897	–	–	–	–	+	–	–	–	+	–	–	–
Hilta	Germany	1983	+	/	+	+	+	+	+	+	+	/	+	+
Lorch	Russia	1931	+	+	+	+	+	+	+	+	+	/	+	+
Lugowskoy	Ukraine	1987	+	+	+	+	+	+	+	+	+	/	+	+
Naroch	Belarus	1986	+	+	+	+	+	+	/	+	+	+	+	+
Provita	Netherlands	1967	+	+	+	+	+	+	+	+	+	+	+	+
Switanok kiewskiy	Ukraine	1987	+	+	+	+	+	+	+	+	/	+	+	+
Sineglaska	Russia	-	+	+	+	+	/	+	+	+	+	+	+	+

Material and Methods

Twelve commercial potato cultivars, which are long-term stored in the genebanks of Groß Lüsewitz and St. Petersburg were analysed (Tab. 1).

DNA was extracted from fresh-leaf tissue of greenhouse and *in vitro* grown plants according to WIENAND and FEIX (1980). Twelve sets of primer sequences were used. The source genes and SSR repeats are given in Table 2. PCR was performed as described by KAWCHUK et al. (1996) with some modifications. The PCR products were separated on non-denaturing polyacrylamide gels and silver stained according to BUDOWLE and ALLEN (1993). The banding patterns were scored visually.

Results and Discussion

As expected for highly heterozygous, clonally propagated species like potato, PCR-based markers are able to generate significant levels of DNA polymorphism to discriminate genotypes. Using twelve pairs of SSR primers it was possible to distinguish all the twelve cultivars, which have been stored up to 48 years separately in different genebanks located at Groß Lüsewitz and St. Petersburg, respectively. Scorable bands were counted for all genotypes. Identity of banding patterns between genebank accessions was detected for ten of the twelve cultivars (Tab. 1, Fig. 1). However, in the cultivars ‘Early Rose’ (Fig. 2) and ‘Epicure’, differences in banding patterns were found for five and ten SSR primer pairs, respectively (Tab. 1, Fig. 3). The following reasons are conceivable:

- Inclusion of donor cultivars carrying genetic modifications at the start of the collection.
- Occurrence of genetic changes during long-term storage caused by the use of growth retardants or environmental stress in handling of *in vitro* and *in situ* collections.
- Instability of the cultivar.
- Mistakes or mixing of cultivars during the activities of the conservation methods.

Genotypes with different banding patterns should be further tested by comparison of morphological traits according to the description of the cultivar list. Material of the same cultivar should be ordered from a third genebank to compare the fingerprints.

First results showed that DNA fingerprinting with SSR primers is a useful, rapid and reliable method to check cultivar identity in genebank collections. In further experiments additional cultivars and other types of germplasm like wild potato species will have to be included.

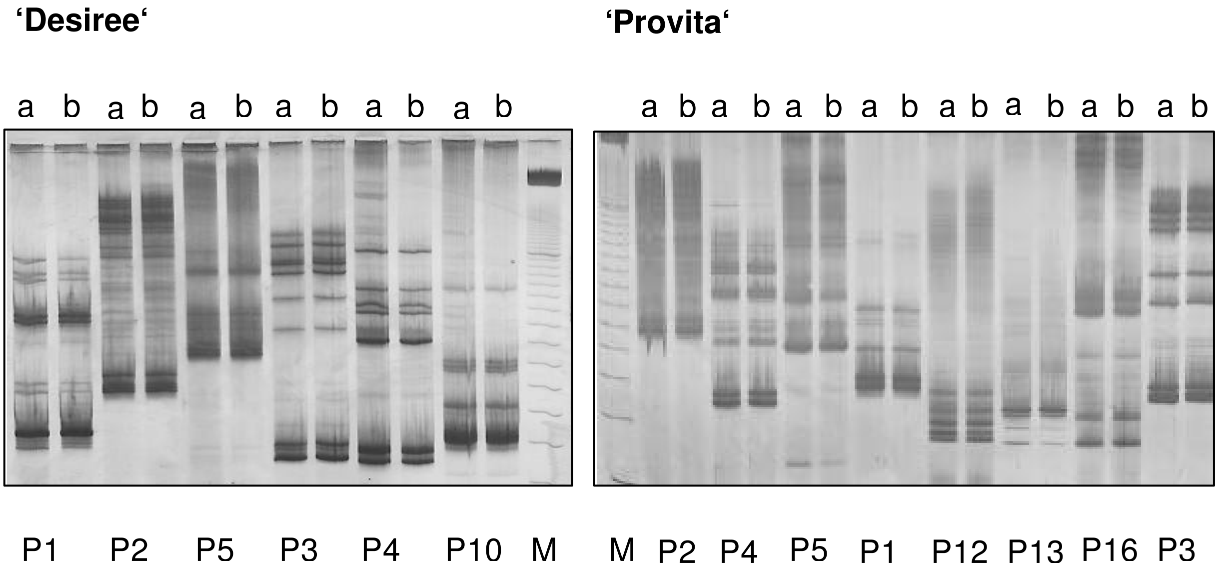

Fig. 1: Polyacrylamide gels depicting polymorphisms with different SSR primer pairs (P) between the cultivars ‘Desiree’ and ‘Provita’ stored in the genebanks of Groß Lüsewitz (a), and St. Petersburg (b), M=100 Base-Pair Ladder

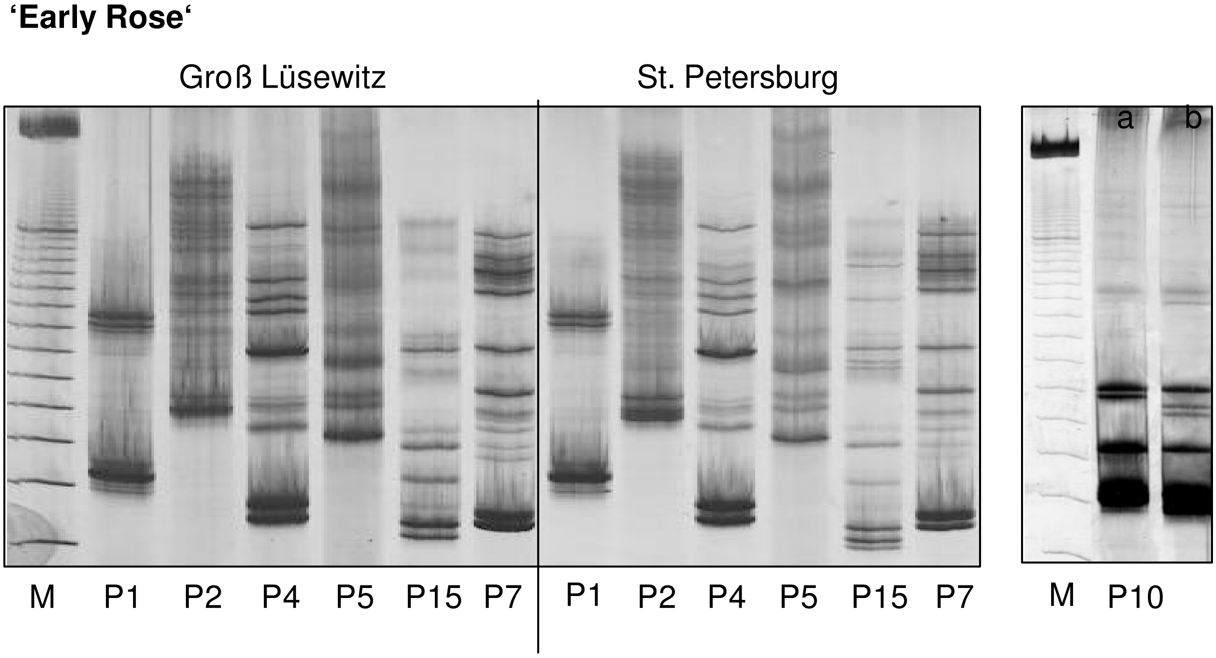

Fig. 2: **Identical and different banding patterns obtained with six (P1, P2, P4, P5, P15, P7) and one SSR primer pair (P10), respectively of the cultivar 'Early Rose' stored in the genebanks of Groß Lüsewitz (a), and St. Petersburg (b), M=100 Base-Pair Ladder**

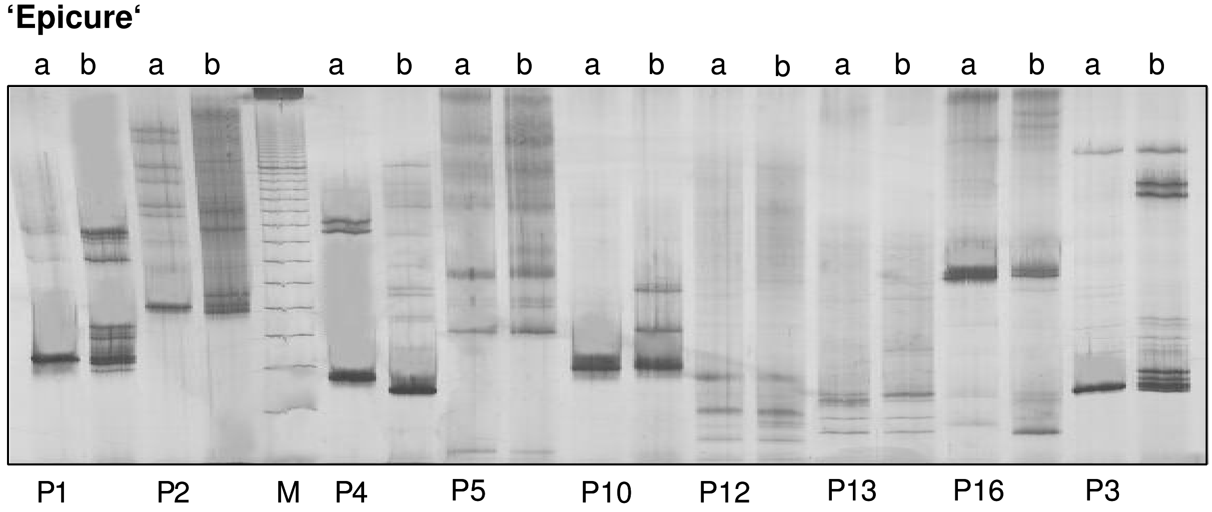

Fig. 3: **Differences of banding patterns of the cultivar 'Epicure' from the genebank collections Groß Lüsewitz (a), and St. Petersburg (b) as revealed by SSR primer pairs P1, P2, P4, P10, P13, P16 and P3, M=100 Base-Pair Ladder**

Conclusions

- SSR primers are useful to generate fingerprints for identification and characterisation of potato germplasm in genebanks.
- DNA profiles generated with SSR primers should prove helpful in producing an index which may be used to control the identity of genebank potato materials after long-term storage.

Acknowledgement

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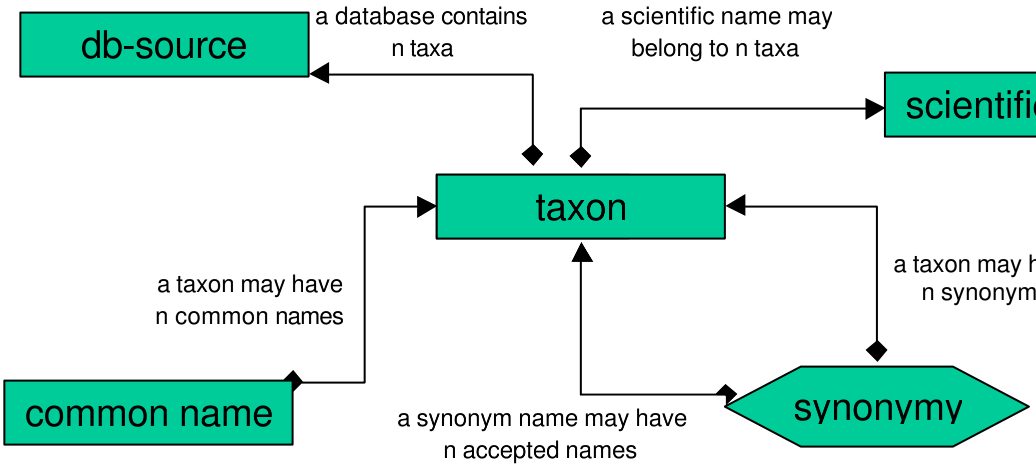
BIGTAX - Repository for scientific and common names of plants

E. Boos[1], W. Braun[2], R. May[3] and J. Ochsmann[4]

The main access path to the information in the Federal Information System Genetic resources (BIG; Bundesinformationssystem Genetische Ressourcen, see Roscher et al. 2003) is the search for taxa by their name. All factual data is connected to taxa. The taxa have scientific or common names and each database has its own list of names and its own synonymy.

The search for names is supported by a central repository, which contains the scientific names of each searchable database and - if existing - their common names and the synonymy. A simple entity-relationship model of the data structure is shown below:



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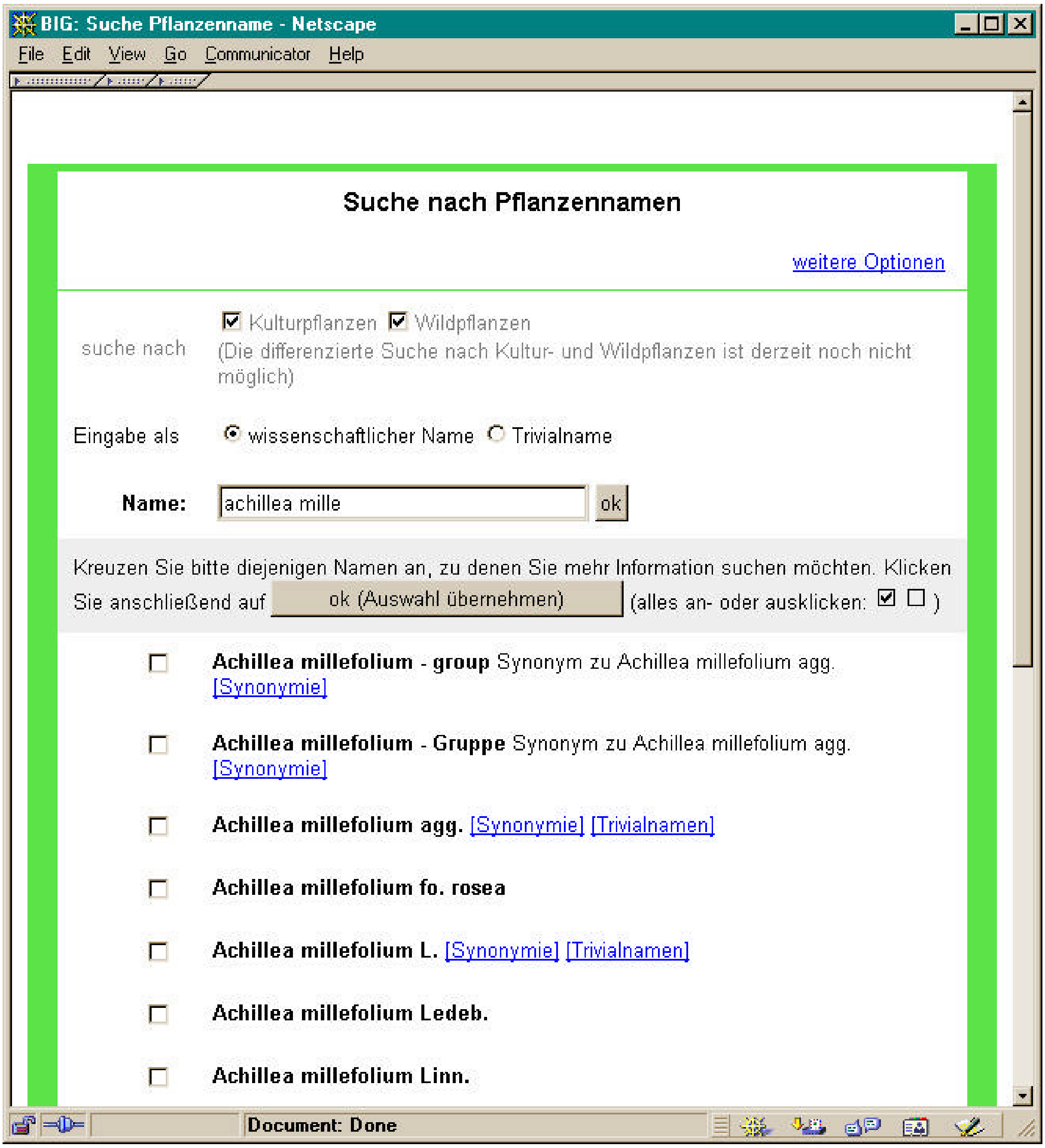
Structure of table ScientificName

Label	Format	Nullable	Send	Comment
id_name	number		y	primary key
id_rank	number		y	foreign key, points to table rank
id_rank_2	number	y	y	foreign key, points to table rank, used for the 'botanical part' of a cultivar name
name	varchar2(512)		y	taxon name
name_1	varchar2(100)	y	y	first name part of bi- or trinomina, single name of higher taxa without authors or other supplementary phrases
epi_1	varchar2(100)	y	y	1st epitheton (species, sectio etc.)
epi_2	varchar2(100)	y	y	2nd epitheton (the last below species)
cultivargroup	varchar2(100)	y	y	
cultivar	varchar2(100)	y	y	
author_phrase	varchar2(100)	y	y	all authors incl. phrases like 'auct.' etc.
bp_standard	number	y	y	authors checked according to Brummitt and Powell (1992)
hybrid	varchar2(1)	y	y	'x' if hybrid, '+' if graft-chimaera

The names are not only stored as strings, but in an atomised form - each name part, the rank and the authors in a single field. At present one can get information on 225,000 taxa via BIGTAX, but the redundancy of names is about 30%. The main causes of redundancy are differences in the spelling of names and their authors.

The atomised structure of names will allow, at a later stage of development, the comparison and improvement of the names and authors and their spelling.

At this time, a search for names will result in a list from which the user can select the names he is interested in, and view their common names or the synonymy. In a next stage it will be possible to search the repository by a hierarchy tree, which is based on a preferred taxonomic view, but maps all used names to this tree.



Suche nach Pflanzenamen

weitere Optionen

suche nach ☑ Kulturpflanzen ☑ Wildpflanzen
(Die differenzierte Suche nach Kultur- und Wildpflanzen ist derzeit noch nicht möglich)

Eingabe als ● wissenschaftlicher Name ○ Trivialname

Name: achillea mille ok

Kreuzen Sie bitte diejenigen Namen an, zu denen Sie mehr Information suchen möchten. Klicken Sie anschließend auf ok (Auswahl übernehmen) (alles an- oder ausklicken: ☑ ☐)

☐ **Achillea millefolium - group** Synonym zu Achillea millefolium agg. [Synonymie]

☐ **Achillea millefolium - Gruppe** Synonym zu Achillea millefolium agg. [Synonymie]

☐ **Achillea millefolium agg.** [Synonymie] [Trivialnamen]

☐ **Achillea millefolium fo. rosea**

☐ **Achillea millefolium L.** [Synonymie] [Trivialnamen]

☐ **Achillea millefolium Ledeb.**

☐ **Achillea millefolium Linn.**

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Genebank work for preservation of the genetic diversity of wild apples

R. BÜTTNER [1], M. FISCHER [1], M. GEIBEL [1], P.L. FORSLINE [2] and V.V. PONOMARENKO [3]

Abstract [4]

The centre of diversity of the genus *Malus* is situated in East Asia. In the mountains of western and southwestern China, as many as 20 species can be found (ZHOU 1999). The complex patterns of the origin, domestication and early migration of the domesticated apple (*Malus domestica* Borkh.) have been described by PONOMARENKO (1987). A second cultivated apple (*M. × asiatica* Nakai ex Matsumura) has been used as a local fruit for centuries (PONOMARENKO 1991). About 30 wild species and thousands of cultivars represent the genepool of *Malus*, a large source of traits for multiple use, which needs to be preserved for future generations, either by keeping the trees *in situ* at the natural site (wild species) or on farm, or by preserving grafted trees (cultivars) or seedlings *ex situ*, or seed lots in genebanks. Wild species seeds can be stored at -20 °C for more than 50 years, while dormant scions can be cryopreserved in liquid nitrogen (FORSLINE et al. 1998).

For decades, classical collections of wild and cultivated apples have existed, for example, in Russia and the former Soviet Union (VIR St. Petersburg and its branch stations), the U.S. (Arnold Arboretum, Massachusetts; Geneva, New York), U.K. (Royal Botanic Gardens Kew; Wye College) and Germany (Naumburg; Pillnitz). Mostly, the material was collected a long time ago, exchanged between different arboreta, often as open-pollinated seeds. Often, the original passport data is highly incomplete. Many *Malus* species are represented by a few accessions only. Therefore, the interest in

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[4] A full paper was published in Acta Horticulturae **538** (2000), pp. 39-42.

material from the centres origin of cultivated apple increased (FORSLINE et al. 1996, HOKANSON et al. 1997, FORSLINE 2000, LUBY et al. 2001), and collecting of wild specimens has been revived recently. Evaluation and characterisation, especially for resistances to biotic and abiotic factors, are underway for a number of species from various origins (LUBY et al. 2001). The results are being included in databases and made available through international networks. This is the basis for their utilisation in breeding new cultivars.

It is concluded that further collecting trips are necessary since the original habitats of many accessions in collections are unknown, and most species are represented by a few accessions only. China, as the main centre of diversity of *Malus*, should be a main destination for further collecting. The evaluation of newly collected material is supported by molecular marker methods to create core collections, thus facilitating a more efficient evaluation (FORSLINE 1996, HOKANSON et al. 1998, 2000). Processing and documentation of evaluation data needs to be strengthened. Thus, research work on *Malus* wild species can be shared effectively between different working groups around the world. These co-operative projects will increase the knowledge of the genus *Malus* and enlarge the genetic base for future apple breeding.

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Studies of genetic integrity in genebank collections [1]

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In the Gatersleben genebank about 100,000 accessions are maintained including cereals, legumes, vegetables, oil and fibre plants, medicinal herbs, spice plants, forages and tubers (potatoes). Depending on the storage conditions and the frequency of providing genebank material to users, regeneration becomes necessary. For that different procedures have to be applied depending on the pollination systems of the particular crops. Especially cross-pollinating species need extended isolation efforts in order to maintain the genetic integrity of the germplasm accessions. However, a contamination by foreign pollen or incorrect handling during multiplication may affect the genetic identity of self-pollinating species as well.

In order to get some information about the integrity of germplasm maintained in the Gatersleben collection, randomly selected accessions of one self-pollinating (*Triticum aestivum* L.) and one cross-pollinating species (*Secale cereale* L.) were investigated by employing molecular markers. The investigation became possible, because in IPK Gatersleben, beside the seeds from the most recent regeneration stored in the cold store, reference (herbarium) collections are maintained. From each cereal accession, samples of grains and complete spikes are deposited as vouchers when they are grown initially. Although the samples are stored at room temperature and, therefore, may have lost their germinability, it is still possible to extract DNA for comparative studies.

Self-pollinating species

Eight wheat (Triticum aestivum L.) accessions differing in their frequency of multiplication were randomly selected out of the Gatersleben genebank wheat collection. The frequencies of multiplication varied between 5 and 24. Five grains of each accession derived from the first and last regeneration cycle were pooled for DNA extraction. Nine

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[1] This presentation is a summary of two extended papers published (Theor. Appl. Genet. 100 (2000) 494-497) and in preparation for the journal Theoretical and Applied Genetics.

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primer pairs of wheat microsatellites with different chromosomal location were chosen for analysis. PCR reactions and fragments detection were performed as described by Röder et al. (1995, 1998).

The analyses of the stocks multiplied up to 24 times show a high degree of identity with the most original material. No contamination due to foreign pollen or incorrect handling during the multiplication cycles was discovered. For one accession (TRI 4599), some genetic drift was observed whereas for TRI 249 a heterogeneous situation for two markers was maintained over the years. The results indicate the high quality of maintenance of self-pollinating genebank accessions in Gatersleben for more than 50 years.

Cross-pollinating species

From the Gatersleben rye (*Secale cereale* L.) collection, four accessions were analysed up to now, regenerated 8, 12 (twice) or 14 times, respectively. Since the rye accessions represent populations, 36 seeds from both the first and most recent regeneration cycle of each accession were used for extracting DNA from single grains. Seven rye microsatellites (RMS) were chosen for analysis. PCR reactions and fragments detection were performed as described for wheat (RÖDER et al. 1995, 1998).

It was shown that in 26 of the 28 analysed accession/marker combinations less alleles (nearly 50%) were discovered after regenerating the material. In 14 cases alleles were found in the recent population, which were not observed in the investigated plants of the original one. RMS makers turned out to differ in their efficiency. Whereas for RMS10 only five alleles were detected, RMS12 was shown to be much more polymorphic having 27 alleles. In continuation of the experiments, only highly informative RMS markers will be utilised. As a conclusion from these results, the population sizes and field plot distances used for the regeneration of cross-pollinating species should be reconsidered.

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Towards a molecular taxonomy and localisation of origin in the *Solanum nigrum* complex

K.J. DEHMER [1]

Abstract

Molecular markers were employed within the taxonomically difficult *Solanum nigrum* complex in order to characterise the genetic diversity present in the IPK genebank accessions, to obtain new insights into the taxonomic subdivision of the complex, to classify unknown accessions and to attempt an approximate localisation of the geographic origin of accessions with unknown provenance.

After examining 69 entries from seven species, an initial species attribution of the material seems already feasible by using only two SSR primer pairs. The respective results, in some cases yielding hardly any differences at all between certain species towards a differentiation on an interspecific level, were confirmed by AFLP analyses. In the latter, unexpectedly high levels of infraspecific variation could be found as well, despite geographically close origins. Furthermore, by the reflection of the provenance of the material in several of the resulting clusters, clues on the currently unknown origin of some of the genebank material might be obtained.

Overall, the two employed marker systems made it possible to classify at least 19 former *Solanum* sp. accessions and to correct the classification of seven black nightshade accessions.

Reference

DEHMER, K.J. (2001): Conclusions on the taxonomy of the *Solanum nigrum* complex by molecular analyses of IPK germplasm accessions. In: R.G. VAN DEN BERG, G.W.M. BARENDSE, G.M. VAN DER WEERDEN and C. MARIANI (Eds.): Solanaceae **V**: Advances in taxonomy and utilization. Proceedings of the Vth International Solanaceae Conference, July 23-29th 2000, Nijmegen. Nijmegen University Press, pp. 85-

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Molecular diversity in the genus *Amaranthus*

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Abstract

40 *Amaranthus* accessions from the IPK genebank and other donors, comprising 13 species, were examined by AFLPs in order to determine the genetic diversity in this genus. The phenogram obtained after evaluating three primer combinations and a total of 893 fragment size classes shows three main clusters, perfectly corresponding to the genepools described for grain amaranth breeding. Furthermore, in almost all cases species-specific subclusters were encountered; only the species of the grain amaranth group displayed an ambiguous grouping.

Introduction

The genus *Amaranthus* includes about 60 species, some of them being cultivated for more than 5.000 years for their grains (*A. caudatus, A. cruentus, A. hypochondriacus;* all from Central/Southern America) or leaves (*A. blitum/lividus;* Central Europe, *A. dubius;* Central America, *A. tricolor;* India/Southern China).

Amaranths, despite having been neglected over many years, are a promising food crop, mainly due to their resistances to heat, drought, diseases and pests. In addition, the nutritional value of both the seeds and leaves is excellent. With regard to their high grain protein concentration of 14-18%, they are superior to corn and other major cereal foods which contain only about 10%, the lysine level in the grain protein being double that of wheat (NRC 1989; SAUNDERS and BECKER 1984), and the greens containing various vitamins and trace elements (SREELATHAKUMARY and PETER 1993). Simultaneously, the genus contains two of the most wide-spread and severe weeds world-wide, *A. retroflexus* and *A. viridis.*

For an initial survey on the applicability of (identical primer combinations of) AFLPs on more than a dozen species – in which it is sometimes difficult to distinguish, e.g., the weedy *A. retroflexus* from genetic resources such as *A. hybridus* and *A. powellii* by col-

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our and growth habit (SAUER 1967) - a set of 40 accessions of both crop and weed type amaranths was subjected to molecular diversity analyses. The respective phenogram was then checked for correlation of the obtained clusters to taxonomy and the known genepools in grain amaranth breeding.

Material and methods

40 accessions from a total of 13 cultivated or weedy *Amaranthus* species (1-6 entries per species, see Table 1; all AMA accessions being part of the genebank collection, B-AMAs put to disposal by the BASF company, and M-AMAs originating from botanical gardens) were analysed in the experiments described here. This sample was representative for mainly the American grain and the European weed amaranths, while the Asian vegetable group was underrepresented due to a certain lack of respective material in the IPK *Amaranthus* collection.

For the molecular analyses, samples of fresh leaves from 20 individual plants were collected and pooled, ground under liquid nitrogen in an MM300 mixer mill (Retsch), then the DNA was extracted according to DOYLE AND DOYLE (1990) with minor modifications. After quantification in a TKO 100 fluorometer (Hoefer), DNA was restricted with *Eco* RI and *Mse* I, ligated to the respective adapters, preamplified and subjected to the actual AFLP analyses by employing unlabelled *Mse* I+3 and fluorescence-labelled *Eco* RI+3 primers, as described in DEHMER (2001). Reaction products were multiplexed after PCR, loaded onto 6% PAGE-PLUS gels (Amaresco, gel length 36 cm) on an ABI 377 automated sequencer (Applied BioSystems) and run for 5.5 hours at 2.875 kV, with the resulting data being evaluated by the GeneScan 3.1 and Genotyper 2.1 software (Applied BioSystems). The 0/1 matrix thus obtained was used to calculate genetic similarities according to DICE (1945), these being transformed into a UPGMA phenogram with the NTSYSpc software (Version 2.0, Exeter Software); in addition, a bootstrap analysis was performed with the PAUP software (Version 4.0b8, SWOFFORD 1998) in order to confirm the reliability of the phenogram.

Results and discussion

The genetic relationships detected between the different accessions are depicted in Figure 1. Three main clusters are visible, which correspond well to the three grain amaranth genepools described by BRENNER (1990). In the first cluster, the three grain amaranth species and their putative progenitor species are found, together with the weedy *A. retroflexus* separated in another subcluster (prima-ry genepool). *A. palmeri* and *A. rudis*, as the two species of the secondary genepool examined, constitute the second, intermediately related cluster, while *A. albus*, *A. blitoides*, *A. gracilis*, *A. tricolor* and *A. viridis* (all tertiary genepool) can be found in the third, most distant cluster. Overall, a rather clear subclustering according to taxonomy can be observed (indicated by the different shades of grey for the mainly single-species clusters), which is also well supported by the bootstrapping values (not shown). In this context, species designations of probably three accessions have to be revised (AMA152, B-AMA06, B-AMA15; cf. Figure 1/Table 1).

Tab. 1: List of accessions examined with botanical names (and abbreviated species name as 'species code') in comparison to the molecularly determined species designation
proposed reclassifications indicated in bold in the 'Molecular code' column; ?: classification doubtful

Acc. No.	Botanical species according to donor	Species code	Molecular code
AMA028	*Amaranthus hybridus* L. em. Robins. convar. *erythrostachys* (Moq. in DC.) Thell. (= *Amaranthus hypochondriacus* L.)	HYP	HYP?
AMA067	*Amaranthus caudatus* L. ssp. *caudatus* var. *alopecurus* Moq. in DC.	CAU	CAU?
AMA074	*Amaranthus powellii* S. Wats.	POW	POW
AMA079	*Amaranthus viridis* L.	VIR	VIR
AMA084	*Amaranthus viridis* L.	VIR	VIR
AMA089	*Amaranthus powellii* S. Wats.	POW	POW
AMA091	*Amaranthus hybridus* L. em. Robins. convar. *erythrostachys* (Moq. in DC.) Thell. (= *Amaranthus hypochondriacus* L.)	HYP	HYP?
AMA092	*Amaranthus caudatus* L. ssp. *caudatus* var. *caudatus*	CAU	CAU?
AMA093	*Amaranthus retroflexus* L.	RET	RET
AMA096	*Amaranthus albus* L.	ALB	ALB
AMA105	*Amaranthus retroflexus* L.	RET	RET
AMA111	*Amaranthus retroflexus* L.	RET	RET
AMA117	*Amaranthus cruentus* L. em. Thell. convar. *cruentus*	CRU	CRU
AMA121	*Amaranthus quitensis* H. B. K.	QUI	QUI?
AMA126	*Amaranthus tricolor* L. em. Fiori and Paol. convar. *tristis* (L.) Thell. ex Aschers. and Graebn.	TRI	TRI
AMA131	*Amaranthus cruentus* L. em. Thell.	CRU	CRU?
AMA150	*Amaranthus albus* L.	ALB	ALB
AMA152	*Amaranthus tricolor* L. em. Fiori and Paol. convar. *mangostanus* (Jusl.) Thell. ex Aschers. and Graebn.	TRI	RET
AMA156	*Amaranthus hypochondriacus* L.	HYP	HYP?

Tab. 1: Continued

Acc. No.	Botanical species according to donor	Species code	Molecular code
AMA157	*Amaranthus hypochondriacus* L.	HYP	HYP?
AMA160	*Amaranthus hybridus* L. em. Robins. convar. *hybridus*	HYB	HYB
B-AMA01	*Amaranthus albus* L.	ALB	ALB
B-AMA02	*Amaranthus blitoides* S. Watson	BLI	BLI
B-AMA03	*Amaranthus hybridus* L.	HYB	HYB?
B-AMA04	*Amaranthus palmeri* S. Watson	PAL	grain?
B-AMA05	*Amaranthus rudis* J.D. Sauer	RUD	RUD
B-AMA06	*Amaranthus palmeri* S. Watson	PAL	RUD
B-AMA07	*Amaranthus palmeri* S. Watson	PAL	PAL
B-AMA08	*Amaranthus retroflexus* L.	RET	RET
B-AMA09	*Amaranthus retroflexus* L.	RET	RET
B-AMA10	*Amaranthus rudis* J.D. Sauer	RUD	RUD
B-AMA11	*Amaranthus rudis* J.D. Sauer	RUD	RUD
B-AMA12	*Amaranthus rudis* J.D. Sauer	RUD	RUD
B-AMA13	*Amaranthus rudis* J.D. Sauer	RUD	RUD
B-AMA14	*Amaranthus rudis* J.D. Sauer	RUD	RUD
B-AMA15	*Amaranthus tuberculatus* (Moq.) J.D. Sauer	TUB	PAL?
B-AMA16	*Amaranthus gracilis* Desf. / *viridis* L.	VIR	VIR
B-AMA17	*Amaranthus gracilis* Desf. / *viridis* L.	VIR	VIR
M-AMA06	*Amaranthus blitoides* S. Watson	BLI	BLI
M-AMA14	*Amaranthus palmeri* S. Watson	PAL	PAL

Only the grain amaranths and their progenitors seem not to group in accordance with taxonomy. This result might be either due to misclassifications (due to morphological resemblances not improbable; in the case of B-AMA04 and AMA152 very likely) and/or to the close relatedness of this group. According to most authors, each of the cultivated species *A. caudatus*, *A. cruentus* and *A. hypochondriacus* might have either originated from three progenitor species *A. quitensis, A. hybridus* and *A. powellii* independently, or from wild *A. hybridus* as wild progenitor of all three cultivated amaranths, with *A. powellii* and *A. quitensis* involved in the speciation (SAUER 1976).

Fig. 1: UPGMA phenogram of 40 *Amaranthus* accessions, based on DICE similarities calculated with data from three primer combinations and 893 fragment size classes (* accessions to be reclassified)

Definite answers to this question have not been feasible by other recent molecular examinations, either (TRANSUE et al. 1994; LANOUE et al. 1996; RANADE et al. 1997; SUN et al., 1999), although an increase in the number of accessions of the individual species might provide more insight into this topic. As the AFLP primer combinations employed here seem to be applicable in all species of the entire genus, the respective analysis will soon be executed on the entire genebank collection of 151 accessions without additional optimisations.

Acknowledgements

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Genetic diversity and infraspecific classification in flax (*Linum usitatissimum* L.)

A. DIEDERICHSEN, D. KESSLER, P. KUSTERS, J. P. RANEY and K.W. RICHARDS [1]

Introduction

The distinction between fibre flax and linseed is based on agrobotanical differences and is of great practical value for efficient communication in agronomy and trade. Characterisation and evaluation data of the flax world collection at Plant Gene Resources of Canada (PGRC) as presented here are discussed in terms of infraspecific[2] groupings. Infraspecific taxa in flax can be used as units to quantify biodiversity and as tool to manage genebank collections or to discuss biodiversity related issues (DIEDERICHSEN and RICHARDS 2001). Based on the biological species concept, cultivated flax, *Linum usitatissimum* L. subsp. *usitatissimum,* and its wild progenitor, pale flax, *Linum usitatissimum* L. subsp. *angustifolium* (Huds.) Thell., are combined into one botanical species (HAMMER 2001). LINNAEUS (1753) distinguished in his “Species Plantarum” four botanical varieties of cultivated flax based on morphological differences. Early botanists proposed separate species names for oil-seed flax (*Linum humile* Mill.) and flax with spontaneously opening capsules (*Linum crepitans* Boenningh.). ALEFELD (1866) described eleven varieties of cultivated flax, HOWARD (1924) grouped Indian flax into 26 botanical varieties, and ELLADI (1940) described 119 botanical varieties. Later agrobotanists recognised that too much taxonomic splitting caused confusion. DILLMAN (1953) distinguished ten infraspecific groups with several varieties in a mixed formal and informal classification. KULPA and DANERT (1962) reduced the number of botanical varieties to 28 belonging to four convarieties and the most recent formal infraspecific classification by CERNOMORSKAJA and STANKEVIC (1987) distinguished five subspecies of cultivated flax.

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[2] The terms infraspecific and intraspecific can be considered as synonyms. The word infraspecific (= below the species level) is used here. The taxonomic system is considered to represent a hierarchical structure, and the word intraspecific (= within the species) does not indicate this as clearly.

Material and methods

The flax accessions of the PGRC collection were grown at Saskatoon, Saskatchewan, Canada. Evaluation for the seed oil content and fatty-acid pattern was conducted in the oil chemistry laboratory at the Saskatoon Research Centre (J.P. Raney). Collection of agrobotanical characterisation data was combined with seed increase to produce sufficient germplasm for storage and distribution to genebank clients. So far, the data for 2.813 of the about 3.500 accessions of the PGRC flax has been compiled (DIEDERICHSEN and RANEY 2001). For the infraspecific grouping the convarieties as suggested by KULPA and DANERT (1962) were used, because their classification has the most consistent taxonomic keys of all mentioned infraspecific groupings.

Results and discussion

The range of observed expressions for selected quantitative characters in the PGRC flax collection (Table 1) exceeded the diversity in recent Canadian flax cultivars in economically important characters such as plant height, seed weight, oil content, and fatty acid patterns (DIEDERICHSEN 2001).

Tab. 1: Ranges of diversity for selected quantitative characters in flax

Character	n	min	$x_{0.5}$	max	CV (%)
Days emergence-maturity	2782	67	92	112	6.24
Petal width (mm)	2442	3.04	9.67	15.82	17.49
Seeds per capsule (Number)	2098	5.1	8.80	10.60	12.31
Plant height (cm)	2746	20	62	130	24.61
Weight of 1000 seeds (g)	2670	2.83	5.87	11.50	20.6
Oil content in seeds (%)	2672	26.19	38.31	45.63	4.61
∀-linolenic acid (%)	2243	39.59	52.61	66.71	7.51

n=number of accessions; min=minimum; $x_{0.5}$=median; max=maximum; CV=coefficient of variation

This illustrates the potential of the PGRC flax collection for crop improvement. Several qualitative characters (colour of flower parts, capsule shape, seed colour) are excellent indicators of genetic differences, because they are morphological genetic markers. Due to reticular character combinations and due to the high number of possible combinations, confusion may occur when assigning formal infraspecific names to each observed combination. Computerised databases can handle this detailed information very efficiently and substitute to some degree the classical approach of infraspecific classification. The four convarieties defined by KULPA and DANERT (1962) are represented in the PGRC flax collection (Table 2). The linseed cultivars grown widely in Canada fall into the group of intermediate flax; their growing season is shorter than of the large seeded Mediterranean flax. The actualisation of the concepts outlined for plant systematics by N.I. VAVILOV (1935) or R. MANSFELD (1962) is based on observations as presented here.

Tab. 2: Representation of the four convarieties of *Linum usitatissimum* L. subsp. *usitatissimum* in the PGRC flax collection

Convariety	**Common name**	**Accessions**
convar. *crepitans* (Boenningh.) Kulpa et Danert	Dehiscent flax	4
convar. *elongatum* Vav. et Ell.	Fibre flax	296
convar. *mediterraneum* (Vav. ex Ell.) Kulpa et Danert	Mediterranean flax	63
convar. *usitatissimum*	Intermediate flax	2427
Total classified		**2790**

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Fishing in the gene pool: evaluation of barley genetic resources in Europe

D. ENNEKING [1,2] and H. KNÜPFFER [1]

Introduction

The EU GENRES CT-98-104 project (ENNEKING 1999-2002) is concerned with improved access to, and utilisation of, barley germplasm in Europe. The three-year project began in 1999 with 28 partners (breeders, genebanks, public research institutions). In 2001, an additional seven partners from non-EU countries, including several EU candidates, joined the project in its final phase.

Our activities are focussed on two areas:

- Development of an information system for European barley collections comprising passport, characterisation and evaluation data.
- Evaluation of barley germplasm for resistance against various biotic and abiotic stresses.

The European Barley Database

The basis for the information system is an updated version of the European Barley Database (EBDB) (ENNEKING 2001-2002, ENNEKING and KNÜPFFER 2001b). This is being developed as a backbone to link with information related to individual accessions.

The database is an inventory for barley germplasm held in 35 genebanks and for the International Barley Core Collection (BCC, 1,126 accessions, cf. KNÜPFFER and HINTUM 1995, 2003), totalling 155,525 accessions. Three collections from outside of Europe, namely those of the International Center for Research in the Dry Areas, ICARDA, and the Australian Winter Cereals Collection, Tamworth, and the Barley Germplasm Center, Okayama University, Japan, are also included.

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For the passport data, emphasis is being placed on the improvement of georeferencing, standardisation of accession names according to published cultivar inventories (ARIAS et al. 1983, BAUM et al. 1985, BAUMER and CAIS 2000) and compilation of synonymous accession numbers. Important sets of germplasm (i.e., material from the German 1938/39 Tibet expedition, or from expeditions in Nepal 1971, Pakistan 1974, etc., organised by the University of Bangor, Wales, UK.) which were virtually inaccessible due to a lack of documentation detail have now been linked either via collecting, donor and synonymous numbers or on the basis of other clues. For example collecting site names are in some collections recorded as Cultivar or accession names.

Evaluation of the Barley Core Collection for resistance against and tolerance to biotic stresses

The BCC has been conceived as a representative sample of the genetic diversity in the barley gene pool to provide a manageable set of genetically well defined accessions (maximum 2,000 entries) for genetic, characterisation, and evaluation studies (KNÜPFFER and HINTUM 1995).

Screening for resistance against, in the European context, economically important fungal and viral diseases was carried on its complete East Asian, American, European, and partial South-West Asian subsets.

The aim of this study is to provide an overview of the available genetic diversity for disease resistance and to pinpoint particular parts of the genepool for further detailed evaluation.

For the years 1999, 2000 and 2001, a total of 23,899 observations were provided by partners of the project GENRES CT98-104, funded by the European Union. These data were collected during three spring and two winter seasons. 22,571 observations on BCC material were used as the basis for a first analysis. Two further seasons observations (winter 2000 and spring 2001) have been carried out (bringing the total to 41,273 observations) but have not been completely included in the present analysis.

Resistances against *Pyrenophora teres* and *Rhynchosporium secalis* and the virus diseases (BaYMV complex, BYDV) have been observed in accessions of the BCC. Resistance to *Blumeria graminis* and *Puccinia hordei* is limited in the *H. vulgare* germplasm of the BCC and mainly restricted to well characterised cultivars. It appears that the BCC subset from ICARDA (incl. *H. vulgare* ssp. *spontaneum*) includes promising germplasm for resistance against leaf rust and powdery mildew. Parts of this short paper have been presented at other meetings (ENNEKING and KNÜPFFER 2001a, ENNEKING et al. 2001).

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E.N. SINSKAYA'S inventory of plant taxa in the basic and dependent areas of the historical development of the flora of cultivated plants

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Abstract

The theory of centres of origin of domesticated plants was established and developed by N.I. VAVILOV, based on many years of systematic study of cultivated plants by the staff of the N.I. Vavilov Institute of Plant Production (VIR), involving hundreds of cultivated plant species collected from all over the globe. This theory was methodically verified.

The boundaries of these centres or areas and the geographical ranges of the crops grown in them were continually updated by N.I. VAVILOV to gain precision, with the help of infraspecific ('differential') systematics. SINSKAYA (1969), in her basic work "Historical geography of the cultivated flora (at the dawn of agriculture)", performed a 'differential' analysis of the composition of cultivated plant resources on the specific and infraspecific levels. She also traced the distribution and endemism of genera, thus expanding the methods for defining centres of origin, and thereby drew our attention to the fact that VAVILOV'S concept of a centre of origin was increasingly associated with wide geographic areas. SINSKAYA described the African area of historical development of the flora of cultivated plants for the first time and introduced the term 'dependent area'. The documentation of domesticated plants by the methods of SINSKAYA gives new inspiration for further research on the evolution of the flora of cultivated plants.

Introduction

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In the literature devoted to the origin of domesticated plants, references to SINSKAYA'S book "Historical geography of the cultivated flora (at the dawn of agriculture)" (SINSKAYA 1969) are rarely found. Its first version was completed in 1952 and handed over to ZHUKOVSKY for review. However, the book was not published until 1969.

Some subsequent publications show a misunderstanding of her valuable contribution to this field, principal reasons being the limited circulation of her book, and the linguistic barrier. SINSKAYA'S work is an organic continuation of VAVILOV'S studies. VAVILOV developed his theory and constantly improved its methodology and terminology. Alongside the term "centre", he always used the concept of "area" of origin. SINSKAYA preferred this latter term, which emphasised VAVILOV'S concept of the polycentric nature of the origins of agriculture. She formalised VAVILOV'S method of definition of the centres to permit their more accurate characterisation as areas of origin of domesticated plants, and to reveal their influence on the development of agriculture worldwide.

The English terminology used in this paper intends to reflect the original Russian terminology used by SINSKAYA.

Methods for determining the centres of type-formation of cultivated plants

To establish centres of type-formation (or centres of diversity), the "differential phytogeographical method" (VAVILOV 1935) was employed. It includes the following steps:

1. Strict differentiation of the plants studied into Linnaean species and infraspecific groups by all available means of various disciplines, such as morphology, agrobotany, phytopathology, cytology.
2. Delimitation of the present distribution areas of these plants and also, if possible, their distribution in the remote past, when communication and seed exchange were more difficult.
3. Determination of the varietal composition of each species (i.e., their botanical varieties, based on morphological characters), and of the general system of genetic diversity within each species.
4. Establishment of the distribution of the genetic diversity of the forms of a given species by regions and areas, and of the geographical centres where these varieties are now accumulated. Regions of maximum diversity, usually also including a number of endemic varietal types and characteristics, can also be centres of type-formation.

5. For a more exact definition of a centre of origin and type-formation, it is necessary to establish the geographical centres of concentration of botanically closely related species as well.
6. Finally, establishment of the areas of diversity of closely related wild subspecies and species of the cultivated species in question should be used for the amendment of, and addition to, the area defined as an area of origin, when the differential method for studying races is applied to them.

Here VAVILOV also accorded great significance to the data of archaeology, linguistics and other sciences.

Progress in many branches of the biological sciences, such as the investigation of the centres of origin of domesticated plants, closely depends on a practical species concept. VAVILOV (1935; published 1992, p. 323) specified his view of the species as the main criterion for defining centres of origin of domesticated plants (see steps 1, 2) as follows: "Our initial aspirations were directed mainly toward the study of difficult subjects such as wheats, rye, barley, maize and cotton which are at present grown widely all over the world and have already long since been dispersed from their primary centres, where they were initially taken into domestication. For such plants, the total areas of the species provide only superficial ideas, if attention is not paid to the formation of their varieties and forms. In order to solve the problem of original areas, the differential method needs to be applied, as it has been used already for discovering the multitude of new varieties and new characteristics and also for revealing new species of wheat, many of which proved to have an amazingly limited distribution."

SINSKAYA founded a new era of cultivated plant research which analysed the species experimentally as a complex system of populations generated in nature. Her theory of populations is based on a synthesis of data from genetics, ecology, comparative physiology, and systematics (SINSKAYA 1931,1969).

MANSFELD (1962, p. 31) also emphasized the importance of detailed systematic analyses of the diversity in domesticated plants, using all available methods to develop practical morphological descriptions of taxa, based on various characters: *"Damit sind die Arten zweifellos natürliche, inhärente Gruppen der Mannigfaltigkeit. Durch die Geschichte der Systematik wie der Biologie zieht sich das Bestreben, die Arten adäquat zu erkennen und darzustellen, theoretisch und praktisch zu definieren, ohne daß man sich bis heute darüber hat einigen können."* ["Therefore, species are undoubtedly inherent natural groups of diversity. Throughout the history of systematics as well as biology, there has been a continual effort to recognise and represent species adequately and to define them theoretically and practically, but without having been able to come to an agreement about that even now."]

"Es ist dagegen eingewendet worden, die Aufstellung und Benennung so vieler Varietäten erschwere die Übersicht. Es läßt sich aber die Mannigfaltigkeit einer Sippe allgemein nur so erfassen und darstellen, daß man die unterscheidbaren Untergruppen beschreibt und benennt. Solche gibt es bei polymorphen Sippen eben sehr viele." ["It has been objected that the setting up and naming of so many varieties complicates the overall view. However, in general, the diversity of a group can only be grasped and displayed by describing and naming the subgroups that can be distinguished, of which there are very many in polymorphic species."] (MANSFELD 1951, p. 41).

SINSKAYA (1966) continued VAVILOV's work to establish the boundaries of the centres of origin of cultivated plants and to specify the relationships between these centres (areas). At present, botanical investigations concerning centres of origin continue, and the collections made are being thoroughly studied. Many amendments can be made to VAVILOV'S theories concerning the centres of origin of cultivated plants but all amount only to correction of details: "The basic composition of cultivated plants, typical of a particular centre, remains stable" (SINSKAYA 1966). With respect to the historical character of VAVILOV'S work, SINSKAYA draws our attention to the prevalent use of the terms "historical-geographical area" and "geographical areas of historical development" (of a cultivated flora) which appear regularly in VAVILOV'S papers (1924-1940; see FILATENKO et al. 1999). This is the main new item in her methodological approach.

Tab. 1: Basic areas of historical development of the flora of cultivated plants (after SINSKAYA 1966, 1969)

Area		Sub-Area
I. Ancient Mediterranean	I.1.	Southwest Asia
	I.1.1.	Anterior Asia (western Southwest Asia: Transcaucasus, Asia Minor, Near East, Iraq, West Iran)
	I.1.2.	Middle Asia (eastern Southwest Asia: Turkestan, Afghanistan, East Iran, Northwest India, Pakistan)
	I.2.	Mediterranean
II. East Asia	II.1.	Northeast Asia (Japan, Manchuria)
	II.2.	Southeast and Central China
III. South Asia	III.1.	South China, India and Sri Lanka
	III.2.	Malesia
IV. Africa		
V. New World	V.1.	Central America
	V.2.	South America

New contributions of E.N. SINSKAYA to N.I. VAVILOV'S theory of the origin of cultivated plants

1. SINSKAYA elaborated a more detailed approach to the analysis of cultivated plants in their centres of origin, called the "differential method of analysis". This approach is based on the differential characterisation of the endemism of various taxa in a given area, which are divided into the following categories:
   a) genera which include cultivated species, and which originated in the area;
   b) genera which include cultivated species, and which have their primary centres of origin or their most important secondary centres of origin in the area;
   c) cultivated species strictly endemic to the given area, having their origin from wild species in that area;
   d) cultivated species endemic to the given area, but having their origin from wild species in another area;
   e) cultivated species which have their primary centres of origin or their most important secondary centres of origin in the area, or which are represented by endemic taxa.

   SINSKAYA (1966, 1969) proposed to differentiate five basic geographical areas of historical development of cultivated plants (Fig. 1, Table 1), with corresponding sub-areas. For these areas and their subdivisions, SINSKAYA (1969) listed the respective cultivated species together with their classification according to the above-mentioned categories (cf. Appendix 1).
2. In addition, SINSKAYA provided a group of genera, species of which have been domesticated both in the Old and in the New World: *Amaranthus* L., *Bromopsis* Fourr., *Chenopodium* L., *Crataegus* L., *Diospyros* L., *Eugenia* L., *Fragaria* L., *Gossypium* L., *Grossularia* Mill., *Juglans* L., *Lupinus* L., *Malus* L., *Phaseolus* L., *Prunus* L., *Solanum* L., *Vitis* L..
3. Developing VAVILOV'S ideas on centres of origin, SINSKAYA (1966) described the African area of historical development of the flora of cultivated plants.
4. The concept of dependent areas of historical development of the flora of cultivated plants was introduced, based on VAVILOV's concept of secondary centres of diversity. Agriculture in such areas is always younger, although the period of their development is still long, as can be judged from the large number of species domesticated from the wild flora of these areas. These dependent areas have the following characteristics:
   1) The endemic flora is often not as rich and not as old as in other areas.
   2) The history of agriculture is not as old.

3) Few or no species have been domesticated there, let alone spread to other areas.
4) Fewer species and forms of wild-growing plants have been introduced into cultivation.
5) No or very few endemic genera that include species of domesticated plants.
6) If there are endemic cultivated plants, they are neither economically nor agriculturally of greater importance in this area.
7) These areas are areas of introduction of domesticated plants from elsewhere rather than areas of their distribution to other places.

The flora of cultivated plants in dependent areas consists of elements from the ancient basic areas of development of cultivated plants. Agriculture in these large regions developed under the influence of the basic areas. For example, agriculture in North America developed mainly on the basis of Mexican and Central American crops and, later on, on crops from the Old World. In Central and Northern Europe, on the Russian Plain and in Siberia, agriculture is based primarily on domesticated plants introduced from Asia Minor and regions around the Mediterranean, etc. Ancient Mediterranean elements and southwestern Asiatic ones predominate in the domesticated flora of Ethiopia but are not clearly delimited from those of other African areas. Elements from southern Asia occur there as well.

However, in the dependent areas, indigenous domesticated plants always occur, and it is necessary to consider these elements separately.

Results

The cultivated species, which according to SINSKAYA have been the main components of plant production since ancient times in each basic area of historical development of the flora of cultivated plants, i.e., in the main areas of origin of agriculture and horticulture, are listed in Appendix 1. The species of the dependent areas are given in Appendix 2. In the Mediterranean, SINSKAYA separated Egypt as one of the most ancient centres of agriculture. Together with the indigenous species of cultivated plants, an astonishing diversity of endemic varieties and forms occurred in a large number of species (ca. 50), which had been introduced into the country ca. 8,000-7,000 years ago (Appendix 3).

The 'differential method of the analysis' of the cultivated floras gives a much better idea of their origin and evolution. Thus, the level of knowledge of biodiversity of each crop and its geographical distribution is of fundamental importance.

Fig. 2: Periods of the emergence of food-producing economy (after SHNIRELMAN 1989)

Besides biogeographical data, SINSKAYA actively involved archaeological data from the literature. This was quite unusual at that time and was reflected in the title of her book "Historical geography of the cultivated flora", which provided a global overview of palaeoethnobotanical data on this problem. The tremendous recent success of archaeology provides more precise information on the origin of agriculture. One of the most comprehensive compilations (more than 1,000 references) of such data is the monograph "The emergence of food-producing economy" (SHNIRELMAN 1989), in which the historical dynamics of relations between the basic areas of development of the flora of cultivated plants is shown (Fig. 2). The time factor, in combination with biogeographical data, can considerably enrich our knowledge of the development of agriculture in the world.

Conclusions

The 'differential analysis' approach to studies on the origin of cultivated plants allows us to specify the boundaries of the areas of historical development of the flora of cultivated plants and the routes of their expansion. Many new data from geography, history and the taxonomy of cultivated plants have been accumulated. Taking SINSKAYA's views into account will promote our knowledge of the development of agriculture on the Earth, increase the efficiency of screening for valuable breeding material, and improve research methods for the study of plant genetic resources maintained in genebanks.

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Appendix 1: SINSKAYA'S inventory of plants in the basic areas of historical development of the flora of cultivated plants

I. ANCIENT MEDITERRANEAN AREA

Genera which include cultivated species, and which originated in the area and have undergone polytopic domestication here

Beta L.
Brassica L.
Carthamus L.
Daucus L.
Hordeum L.
Lens Mill.
Linum L.
Mandragora L.
Medicago L.
Melilotus Mill.
Pisum L.
Raphanus L.
Trigonella L.
Triticum L.

I.1. Southwest Asian sub-area

Genera which include cultivated species, and which have their primary centres of origin, or their most important secondary centres of origin in the area

Genera with largest diversity in **Anterior Asia** (western Southwest Asia)

Agropyron Gaertn.
Amygdalus L.
Avena L.
Beta L.
Camelina Crantz
Carthamus L.
Cerasus Mill.
Cicer L.
Corylus L.
Crataegus L.
Cydonia Mill.
Elytrigia Desf.
Ficus L.
Lallemantia Fisch. et Mey.
Lens Mill.
Medicago L.
Mespilus L.
Onobrychis Mill.
Pistacia L.
Pisum L.
Prunus L.
Punica L.

Pyrus L.
Secale L.
Sorbus L.
Trifolium L.
Triticum L.
Vicia L.

Genera with largest diversity in **Middle Asia** (eastern Southwest Asia)
Brassica L.
Carthamus L.
Ficus L.
Linum L.
Malus Mill.
Melo Mill. emend. Pang.
Pistacia L.
Pyrus L.

I.1.1. Anterior Asia (western Southwest Asia)

Cultivated species strictly endemic to the given area, having their origin from wild species in that area
Atropa caucasica Kreyer (*A. bella-donna L.* ssp. *caucasica* (Kreyer) V. Avet.)
Camelina caucasica Sinskaya (*C. sativa* (L.) Crantz ssp. *sativa*) [Transcaucasia]
Galega orientalis Lam.
Lallemantia iberica (M. Bieb.) Fisch. et C.A. Mey. [Ancient Armenia]
L. peltata (L.) Fisch. et C.A. Mey.
L. rupestris Sinskaya et Voskr.
Malus orientalis Uglitzk.
Medicago glutinosa M. Bieb. s.l.
M. jemenensis Sinskaya (*M. sativa* L. ssp. *sativa*) [Yemen]
M. mesopotamica Vassilcz. (*M. sativa* L. ssp. *sativa*)
M. orientalis Vassilcz. (*M. sativa* L. ssp. *sativa*) [Anterior Asia]
M. praesativa Sinskaya (*M. sativa* L. ssp. *sativa*) [Ancient Armenia]
M. quasifalcata Sinskaya (*M. sativa* L. ssp. *falcata* (L.) Arcang.)
M. syriaco-palestinica (Bordj.) Sinskaya (*M. sativa* L. ssp. *sativa*)
Onobrychis altissima Grossh.
O. antasiatica Chinchuk
O. biebersteinii G. Sirjaev
O. cyri Grossh.
O. meschetika Grossh.
O. transcaucasica Grossh.
Pimpinella anisetum Boiss. et Balansa
P. aromatica M. Bieb.
Pyrethrum carneum M. Bieb. (*Tanacetum coccineum* (Willd.) Grierson, *Chrysanthemum coccineum* Willd.)
P. roseum (Adams.) M. Bieb. (*Tanacetum coccineum* (Willd.) Grierson, *Chrysanthemum coccineum* Willd.)

Pyrus caucasica Fed.
*P. syria*ca Boiss.
P. takhtadzhianii Fed.
Rosa damascena Mill.
Satureja spicigera (K. Koch) Boiss. (*S. alternipilosa* C. Koch)
Trifolium apertum Bobrov
Trigonella jemenensis (Serp.) Sinskaya (*T. foenum-graecum* L.)
Triticum ?arthlicum Nevski (*T. turgidum* L. ssp. *carthlicum* (Nevski) A. et D. Löve)
T. ispahanicum Heslot [Iran]
T. k?ramyschevii Nevski (*T. turgidum* L. ssp. *georgicum* (Dekapr. et Menabde) MacKey ex Hanelt
T. macha Dekapr. et Menabde (*T. aestivum* L. ssp. *macha* (Dekapr. et Menabde) MacKey)
T. timopheevii (Zhuk.) Zhuk.
T. turanicum Jakubz. (*T. turgidum* L. ssp. *turanicum* (Jakubz.) A. et D. Löve
T. vavilovii Jakubz. (*T. aestivum* L. ssp. *spelta* (L.) Thell.) [Armenia]
T. zhukovskyi Menabde et Ericzjan

Cultivated species having their primary centres of origin or their most important secondary centres of origin in the area, or which are represented by endemic taxa
Agropyron cristatum (L.) Gaertn. s.l.
Amygdalus communis L.
Anthriscus cerefolium (L.) Hoffm.
Armeniaca vulgaris Lam.
Arrhenatherum elatius (L.) J. et C. Presl
Beta vulgaris L.
Brassica campestris L. (*B. rapa* L.)
B. capitata (L.) Lizg. (*B. oleracea* L. convar. *capitata* (L.) Alef.)
B. napoeuropea Sinskaya
B. nigra (L.) Koch
Bromus riparius Rehm. (*Bromopsis riparia* (Rehm.) Holub
Cannabis sativa L.
Carthamus tinctorius L.
Castanea sativa Mill.
Cephalaria syriaca (L.) Roem. et Schult.
Cerasus avium (L.) Moench
C. vulgaris Mill.
Cicer arietinum L.
Coriandrum sativum L.
Cornus mas L.
Corylus avellana L.
?ucumis sativus L.
Dactylis glomerata L.
Daucus carota L. ssp. *maximus* (Desf.) Ball
D. carota L. ssp. *orientalis* Rubasch. (*D. carota* L. ssp. *sativus* (Hoffm.) Schübl. et Mart.)
Eruca sativa Mill.
Festuca pratensis Huds.
F. rubra L.

Ficus carica L.
Foeniculum vulgare Mill.
Helianthus annuus L.
Hordeum distichon L. (*H. vulgare* L. convar. *distichon* (L.) Alef.)
H. vulgare L.
Lactuca sativa L.
Lallemantia iberica (M. Bieb.) Fisch. et C.A. Mey.
Lathyrus cicera L.
L. sativus L.
Lens culinaris Medik.
Lepidium sativum L.
Linum usitatissimum L. s.l.
Lolium perenne L.
Medicago sativa L. s.l.
Melilotus officinalis (L.) Pall.
Melo adana Pangalo (*Cucumis melo* L. ssp. *adana* Pangalo)
M. adzhur Pangalo (*Cucumis melo* L. var. *chate* (Hasselq.) Filov)
M. cantalupa Pangalo (*Cucumis melo* L. var. *cantalupensis* Naudin)
M. cassaba Pangalo (*Cucumis melo* L. ser. var. cassaba Pangalo)
M. microcarpus (Alef.) Pangalo (*Cucumis melo* L. var. *dudaim* (L.) Naud.)
Mespilus germanica L.
Morus alba L.
M. nigra L.
Olea europaea L.
Panicum miliaceum L.
Papaver somniferum L.
Phleum pratense L.
Pistacia vera L.
Pisum sativum L.
Portulaca oleracea L.
Prunus cerasifera Ehrh.
Punica granatum L.
Rheum ribes L.
Ricinus microcarpus Popov (*R. communis* L.)
Secale cereale L.
Sesamum indicum L.
Setaria italica (L.) P. Beauv.
Sinapis alba L.
Solanum melongena L.
Spinacia oleracea L.
Trifolium alexandrinum L.
T. pratense L. s.l.
Trigonella caerulea (L.) Ser.
T. foenum-graecum L.
Triticum aestivum L.
T. dicoccon Schrank (*T. turgidum* L. ssp. *dicoccon* (Schrank) Thell.)
T. durum Desf. (*T. turgidum* L. ssp. *durum* (Desf.) Husn.)

Vicia faba L.
V. pannonica Crantz
V. sativa L.
V. variabilis Freyn et Sint.
Vitis vinifera L.

I.1.2. Middle Asia (eastern Southwest Asia)

Cultivated species strictly endemic to the given area, having their origin from wild species in that area
Persica ferganensis (Kostina et Rjab.) Koval et Kost.
Prunus ×ferganica Lincz.
Scorzonera tau-saghyz Lipsch. et Bosse
Taraxacum kok-saghyz Rodin

Cultivated species having their primary centres of origin, or their most important secondary centres of origin in the area, or which are represented by endemic taxa
Allium cepa L.
A. sativum L.
Amygdalus communis L.
Apocynum lancifolium Russan. (*Trachomitum lancifolium* (Russan.) Pobed.)
A. scabrum Russan. (*Trachomitum scabrum* (Russan.) Pobed.)
Armeniaca kostiniae E.N.Lomakin
A. vulgaris Lam.
Brassica juncea (L.) Czern.
B. rapa L.
B. rapoasiatica Sinskaya (*B. rapa* L. ssp. *rapa*)
Cannabis indica Lam. (*C. sativa* L. ssp. *indica* (Lam.) Small et Cronq.)
C. sativa L.
Carthamus tinctorius L.
Carum copticum (L.) Benth. (*Trachypermum ammi* (L.) Sprague ex Turill)
?icer arietinum L.
Citrullus lanatus (Thunb.) Matsum. et Nakai
Coriandrum sativum L
Cucumis sativus L.
Cucurbita moschata Duch.
Daucus carota L.
Elaeagnus angustifolia L.
Eruca sativa Mill.
Ficus carica L.
Gossypium herbaceum L.
Hordeum vulgare L
Juglans regia L.
Lathyrus sativus L.
Lens culinaris Medik.
Lepidium sativum L.

Linum usitatissimum L.
Medicago asiatica Sinskaya (*M. sativa* L. ssp. *sativa*)
Melilotus alba Medik.
Melo ameri Pangalo (*Cucumis melo* L. var. *ameri* (Pangalo) Malin)
M. chandalak Pangalo (*Cucumis melo* L. var. *chandalak* (Pangalo) Filov)
M. zard Pangalo (*Cucumis melo* L. var. *inodorus* H. Jacq.)
Morus alba L.
M. nigra L
M. rubra L.
Oryza sativa L.
Panicum miliaceum L.
Papaver somniferum L.
Persica vulgaris Mill.
Pimpinella anisum L.
Pistacia vera L.
Pisum sativum L.
Polygonum coriarium Grig.
Prunus cerasifera Ehrh.
Punica granatum L.
Raphanus sativus L.
Ricinus microcarpus Popov (*R. communis* L.)
Salvia sclarea L.
Secale cereale L.
Sesamum indicum L.
Sorghum durra (Forssk.) Stapf ex Prain
Trigonella foenum-graecum L.
Triticum aestivum L.
T. compactum Host (*T. aestivum* L. ssp. *aestivum*)
T. sphaerococcum Percival
Vicia faba L.
Vigna radiata (L.) R. Wilczek
Vitis vinifera L.
Ziziphus jujuba Mill.

I.2. Mediterranean sub-area

Genera which include cultivated species, and which originated in the area

Carthamus L.
Cynara L.
Eruca Mill.
Lavandula L.
Sinapis L.

Genera which include cultivated species, and which have their primary centres of origin or their most important secondary centres of origin in the area

Lathyrus L.
Lupinus L.
Medicago L.
Melilotus Mill.
Trifolium L.
Vicia L.

Cultivated species strictly endemic to the given area, having their origin from wild species in that area

Ampelodesmos mauritanica (Poiret) T. Durand et Schinz (*A. tenax* (Vahl) Link)
Eruca pinnatifida (Desf.) Pomel
Hedysarum coronarium L.
Lathyrus gorgonii Parl.
L. ochrus (L.) DC.
Lupinus albus L. (*L. termis* Forssk.)
Medicago tripolitanica Sinskaya (*M. sativa* L. ssp. *sativa*)
Spartium junceum L.
Stipa tenacissima L.
Trifolium incarnatum L.
Ulex europaeus L.

Cultivated species having their primary centres of origin or their most important secondary centres of origin in the area, or which are represented by endemic taxa

Allium cepa L.
Apium graveolens L.
Asparagus officinalis L.
Brassica cauliflora Gars. (*B. oleracea* L. convar. *botrytis* (L.) Alef.)
B. oleracea L.
B. rapa L.
Carum carvi L.
Ceratonia siliqua L.
Cucurbita maxima Duch.
Cynara cardunculus L.
Daucus carota L. ssp. *occidentalis* Rubasch. (*D. carota* L. ssp. *sativus* (Hoffm.) Schübl. et Mart.)
Foeniculum vulgare Mill.
Hordeum vulgare L.
Lathyrus odoratus L.
Laurus nobilis L.
Linum usitatissimum L.
Olea europaea L.
Ornithopus sativus Brot.
Papaver somniferum L.
Pastinaca sativa L.
Petroselinum crispum (Mill.) Nym. (*P. hortense* Hoffm.)

Phalaris canariensis L.
Pistacia vera L.
Rhus coriaria L.
Ruta graveolens L.
Satureja hortensis L.
Sesamum indicum L.
Sinapis alba L.
Triticum aestivum L.
T. dicoccon Schrank (*T. turgidum* L. ssp. *dicoccon* (Schrank) Thell.)
T. durum Desf. (*T. turgidum* L. ssp. *durum* (Desf.) Husn.)
T. monococcum L.
T. turgidum L.
Ulex europaeus L.
Vicia faba L.
Vitis vinifera L.
many ornamental species

II. EAST ASIAN AREA

Genera which include cultivated species, and which originated in the area:
Aconitum L.
Actinidia Lindl.
Amygdalus L.
Armeniaca Mill.
Castanea Mill.
Cerasus Mill.
Chaenomeles Lindl.
?hrysanthemum L.
Cinnamomum Schaeff.
?onvallaria L.
Corylus L.
Crataegus L.
Cryptomeria D. Don
Dactylis L.
Elaeagnus L.
Elsholtzia Willd.
Eriobotrya Lindl.
Euonymus L.
Fagus L.
Fortunella Swingle
Grossularia Mill.
Hippophae L
Hydrangea L.
Juglans L.
Kummerowia Schindl.
Lathyrus L.

Lespedeza Michx.
Malus Mill.
Morus L.
Paulownia Siebold et Zucc.
Perilla L.
Persica Mill.
Pinus L.
Pistacia L.
Poncirus Rafin.
Prunus L.
Pyrus L.
Quercus L.
Ribes L.
Roegneria C. Koch (*Elymus* L.)
Schisandra Michx.
Sorbus L.
Syringa L.
Trapa L.
Vicia L.
Wisteria Nutt.
Ziziphus Mill.

Genera which include cultivated species, and which have their primary centre of origin, or their most important secondary centre of origin in the area

Citrus L.
Rubus L.
Thea L. *(Camellia* L.)

Species endemic to this region

Adenophora pereskiifolia (Fisch. ex Roem. et Schult.) G. Don (*A. latifolia* Fisch.)
Allium chinense G. Don
A. macrostemon Bge.
A. pekinense Prokh. (*A. sativum* L. var. *pekinense* (Prokh.) Maekawa)
Amorphophallus konjak C. Koch
Angelica acutiloba (Siebold et Zucc.) Kitag.
Aralia cordata Thunb.
Arctium lappa L.
Asparagus cochinchinensis (Lour.) Merr. (*A. lucidus* Lindl.)
Astragalus sinicus L.
Bolbostemma paniculatum (Maxim.) Franquet (*Actinostemma paniculatum* (Maxim.) Maxim. ex Cogn.)
Brassica alboglabra L.H. Bailey (*B. oleracea* L. var. *alboglabra* (L.H. Bail.) Sun)
B. chinensis L. (*B. rapa* L. ssp. *chinensis* (L.) Hanelt)
B. dubiosa L.H. Bailey (*B. rapa* L. ssp. *chinensis* (L.) Hanelt)
B. napiformis L.H. Bailey (*B. juncea* (L.) Czern. ssp. *napiformis* (Paill. et Bois) Gladis
B. narinosa L.H. Bailey (*B. rapa* L. ssp. *chinensis* (L.) Hanelt)
B. nipposinica L.H. Bailey (*B. rapa* L. ssp. *nipposinica* (L.H. Bailey) Hanelt)

B. pekinensis Rupr. (*B. rapa* L. ssp. *pekinensis* (Lour.) Hanelt)
Cerasus Mill. [ca. 80 species of this genus are endemics of East Asia]
Chrysanthemum × *morifolium* Ramat.
Cyperus malaccensis C.B. Clarke
Dolichos hassjoo Siebold (*Mucuna pruriens* (L.) DC. ssp. *deeringiana* (Bort) Hanelt)
D. montanus Lour. (*Pueraria montana* (Lour.) Merr. var. *montana*)
Elatostema involucratum Franch. et Sav.
Eleocharis tuberosa Schult. (*E. dulcis* (Burm. f.) Trinius ex Henschel)
Eutrema wasabi (Siebold) Maxim. (*Wasabia japonica* (Miq.) Matsum.)
Gardenia florida L.
G. jasminoides Ellis
Glebionis coronarium (L.) C. Jeffrey (*Chrysanthemum coronarium* L.)
Hordeum humile Vav. et Bacht.
Illicium anisatum L.
Ipomoea aquatica Forssk.
Juncus effusus L. var. *decipiens* Buch.
Melo chinensis Pangalo (*Cucumis melo* L. ssp. *chinensis* (Pangalo) Filov)
M. conomon (Thunb.) Pangalo (*Cucumis melo* L. var. *conomon* (Thunb.) Makino
M. monoclinus Pangalo (*Cucumis melo* L. var. *makuwa* Makino)
Myrica rubra (Lour.) Siebold et Zucc.
Panax ginseng C.A. Mey.
Petasites japonicus (Siebold et Zucc.) Maxim.
Peucedanum japonicum Thunb.
Pistia stratiotes L.
Pueraria thunbergiana (Siebold et Zucc.) Benth. (*P. montana* var. *lobata* (Willd.) Maesen et S.M. Almeida)
Raphanus acanthiformis M. Morel ex Sisley (*R. sativus* L. f. *raphanistroides* Makino)
R. sinensis Sinskaya (*R. sativus* L. ssp. *sinensis* Sazon. et Stankev.)
Saccharum sinense Roxb.
Sagittaria sagittifolia L.
Stachys affinis Bunge
S. sieboldii Miq.
Trachycarpus fortunei (Hook.) H. Wendl. (*T. excelsus* H. Wendl.)
Vitis amurensis Rupr.
Zizania latifolia (Griseb.) Turcz.

Cultivated species having their primary centres of origin or their most important secondary centres of origin in the area, or which are represented by endemic taxa

Avena nuda L.
Brassica campestris L.
B. rapa L.
B. rapoasiatica Sinskaya (*B. rapa* L. ssp. *rapa*)
Cannabis sativa L.
Citrus maxima (Burm.) Merrill (*C. grandis* Osbeck)
C. sinensis (L.) Osbeck
Colocasia antiquorum (L.) Schott ex Schott et Endl.
Cucumis sativus L.

Cucurbita maxima Duch.
C. moschata Duch.
Daucus carota L. ssp. *orientalis* Rubasch. (*D. carota* L. ssp. *sativus* (Hoffm.) Schübl. et Mart.)
Fagopyrum esculentum Moench
F. tataricum (L.) Gaertn.
Gossypium arboreum L.
Ipomoea batatas (L.) Lam.
Oryza sativa L.
Papaver somniferum L.
Phaseolus vulgaris L.
Pisum sativum L.
Ricinus macrocarpus G. Pop. (*R. communis* L.)
Sesamum indicum L.
Solanum melongena L.
Stizolobium utile (Wall. ex Wight) sensu Ditm. (*Mucuna puriens* (L.) DC. ssp. *deeringiana* (Bort) Hanelt)
Thea sinensis L. s.l. (*Camellia sinensis* (L.) Kuntze s.l.)
Triticum aestivum L.
Vicia faba L.
Vigna radiata (L.) R. Wilczek
V. sinensis (L.) Hassk. (*V. unguiculata* (L.) Walp. ssp. *unguiculata*)
Zea mays L. convar. *ceratina* Kuleshov

Domesticated species of genera the origin of which is outside of East Asia or has not yet been established with accuracy, having their the basic area of origin and development in East Asia

Abutilon theophrasti Medik.
Aleurites cordata (Thunb.) R. Br. ex Steud.
A. fordii Hemsl.
Boehmeria nivea (L.) Gaud.
Brassica juncea (L.) Czern.
Clausena lansium (Lour.) Skeels
Diospyros kaki L. f.
Echinochloa P. Beauv.
Eucommia ulmoides Oliv.
Euphorbia lathyris L.
Glycine max (L.) Merr.
Litchi chinensis Sonn.
Melia azedarach L.
Morus alba L.
Panicum miliaceum L.
Perilla frutescens (L.) Britton
Setaria italica (L.) Beauv. convar. *moharia* (Alef.) Körn.
Smilax china L.
Sorghum nervosum Besser ex Schult.
Trachycarpus fortunei (Hook.) H. Wendl.

Vigna angularis (Willd.) Ohwi et Ohashi

III. SOUTH ASIAN AREA

Genera which include cultivated species, and which originated in the area

South Asia is rich in endemic genera which include cultivated species (*Mangifera* L., *Garcinia* L., *Artocarpus* J.R. et J.G.A. Forster, and many others). It is also the area of development of the following genera including important species of domesticated plants of global value:

Aleurites J.R. et J.A.G. Forster
?itrus L.
Curcuma L.
Fagopyrum Mill.
Thea L. (*Camellia* L.)

Genera which include cultivated species, and which have their primary centres of origin or their most important secondary centres of origin in the area

Amaranthus L.
Canavalia DC.
Coleus Lour.
Corchorus L.
Crotalaria L.
Cucumis L.
Dioscorea L.
Dolichos L.
Eugenia L.
Gigantochloa Kurz ex Munro
Glycine Willd.
Gossypium L.
Oryza L.
Phaseolus L.
Rubus L.

Cultivated species strictly endemic to to the given area, having their origin from wild species in that area

Anethum sowa Roxb. ex Fleming (*A. graveolens* L. ssp. *sowa* (Roxb. ex Fleming) Gupta)
Areca catechu L.
Averrhoa carambola L.
Basella rubra L. (*B. alba* L.)
Beta indica orientalis Roth
Carum roxburghianum Benth. (*Trachyspermum roxburghianum* (DC.) H. Wolff)
Durio zibethinus Murr.
Lactuca indica L.
Metroxylon sagu Rottb.
Pterocypsela indica (L.) C. Shih
Raphanus indicus Sinskaya (*R. sativus* L. convar. *sativus*)
Salacca zalacca (Gaertn.) Voss (*S. edulis* Reinw.)

Cultivated species having their primary centres of origin or their most important secondary centres of origin in the area, or which are represented by endemic taxa

Aleurites moluccana (L.) Willd.
Amorphophallus paeoniifolius (Dennstedt) Nicolson
Boehmeria nivea (L.) Gaud.
Brassica nigra (L.) Koch
B. trilocularis (Roxb.) Hook. et Thompson (*B. rapa* L. ssp. *trilocularis* (Roxb.) Hanelt)
Cajanus cajan (L.) Millsp.
Cannabis sativa L.
Carthamus tinctorius L.
Cicer arietinum L.
Cocos nucifera L.
Coix lacryma-jobi L.
Colocasia esculenta (L.) Schott ex Schott et Endl.
Coriandrum sativum L.
?ornus capitata Wall. (*Dendrobenthamia capitata* (Wall.) Hutch.)
Cucumis sativus L.
Cucurbita moschata Duch.
Cuminum cyminum L.
Curcuma longa L.
Dioscorea esculenta (Lour.) Burkill
Diospyros blancoi A. DC.
Dolichos lablab L. (*Lablab purpureus* (L.) Sweet)
Echinochloa crus-galli (L.) P. Beauv.
E. frumentacea Link
Elettaria cardamomum (L.) Maton
Eleusine coracan (L.) Gaertn.
E. indica (L.) Gaertn.
Eugenia caryophyllata Thunb. (*Syzygium aromaticum* (L.) Merr. et Perry)
Fagopyrum esculentum Moench
Hibiscus cannabinus L.
Hordeum vulgare L.
Jasminum grandiflorum L.
Lagenaria siceraria (Molina) Standl.
Lathyrus sativus L.
Lens culinaris Medik.
Linum usitatissimum L.
Luffa acutangula (L.) Roxb.
Momordica charantia L.
Musa textilis Née
Myristica fragrans Houtt.
Oryza sativa L.
Paspalum scrobiculatum L.
Phaseolus aconitifolius Jacq. (*Vigna aconitifolia* (Jacq.) Maréchal)
Ph. mungo (L.) Piper (*Vigna mungo* (L.) Hepper)
Phoenix dactylifera L.
Piper nigrum L.

Pisum sativum L.
Plectranthus tuberosus Blume (*Solenostemon rotundifolius* (Poir.) J.K. Morton)
Pogostemon cablin (Blanco) Benth.
Rauvolfia serpentina (L.) Benth. ex Kurz
Ricinus communis L.
Saccharum officinarum L.
Santalum album L.
Sesamum indicum L.
Sesbania bispinosa (Jacq.) W.F. Wight
S. cannabina (Retz.) Pers.
Sida rhombifolia L.
Solanum melongena L.
Sorghum durra (Forssk.) Stapf ex Prain
Stizolobium utile (Wall. ex Wight) sensu Ditm. (*Mucuna pruriens* (L.) DC. ssp. *deeringiana* (Bort) Hanelt)
Tacca leontopetaloides (L.) Kuntze
Trigonella foenum-graecum L.
Triticum aestivum L.
Vigna radiata (L.) R. Wilczek
V. sinensis (L.) Hassk. (*V. unguiculata* (L.) Walp. ssp. *unguiculata*)
Zea mays L.

IV. AFRICAN AREA

Genera which include cultivated species, and which originated in the area

Aloe L.
Citrullus Eckl. et Zeyh.
Cola Schott et Endl.
Coleus Lour.
Crotalaria L.
Cucumis L.
Dolichos L.
Guizotia Cass.
Indigofera L.
Pelargonium L'Herit.
Pennisetum L.C. Rich. ex Pers.
Sesamum L.
Setaria P. Beauv.
Sorghum Moench
Vigna Savi

Genera which include cultivated species, and which have their primary centres of origin or their most important secondary centres of origin in the area

Gossypium L.
Musa L.
Oryza L.

Solanum L.

Cultivated species strictly endemic to the area, having their origin from wild species in that area

In the African area of the development of the flora of domesticated plants plenty of indigenous crop plants are concentrated, e.g.:

Antrocaryon micraster A.Chev. et A.Guill.
Blighia sapida Koenig
Cola acuminata (P. Beauv.) Schott et Endl.
C. nitida (Vent.) Schott et Endl.
Ficus carica L.
Hibiscus aspera Hook. f. in Hook.
Mammea americana L.
Myrianthus arboreus P. Beauv.
Panda oleosa Pierre
Pentadesma butyracea Sabine
Sarcocephalus esculentus Afzel. ex Sabine
Staudtia gabonensis Warburg
Telfairia occidentalis Hook.f.
T. pedata (J. Sm.) Hook.
Treculia africana Decne. ex Trécul
Urena lobata L.

Cultivated species having their primary centres of origin or their most important secondary centres of origin in the area, or which are represented by endemic taxa

Bassia parkii G. Don (*Vitellaria paradoxa* Gaertn. f.)
Colocasia esculenta (L.) Schott ex Schott et Endl.
Dolichos lablab L. (*Lablab purpureus* (L.) Sweet)
Kerstingiella geocarpa Harms (*Macrotyloma geocarpum* (Harms) Maréchal et Band.)
Oryza sativa L.
Polygala butyracea Heckel
Ricinus zanzibaricus G. Pop. (*R. communis* L.)
Sophora alata Sanks.
Syzygium owariense Benth.
Tetracarpidium conophorum (Müll. Arg.) Hutch. et Dalz.
Voandzeia subterranea (L.) Thou. ex DC. (*Vigna subterranea* (L.) Verdc.)

V. NEW WORLD AREA

Genera which include cultivated species, and which originated in the area

Agave L.
Canna L.
Capsicum L.
Cucurbita L.
Dahlia Cav.
Ipomoea L.

Lycopersicon Mill.
Nicotiana L.
Salvia L.
Solanum L.
Tagetes L.
Theobroma L.
Tropaeolum L.
Yucca L.
Zea L.
Zinnia L.
and many others (>40 endemic genera)

Genera which include cultivated species, and which have their primary centres of origin or their most important secondary centres of origin in the area

Canavalia DC.
Eugenia L.
Gossypium L.
Lupinus L.
Phaseolus L.
Rubus L.
Vanilla Mill.
and others

V.1. Central America

Cultivated species strictly endemic to the area, having their origin from wild species in that area

Agave ixtli Karw. ex Salm-Dyck (*A. angustifolia* Haw.)
A. lechuguilla Torr.
A. sisalana Perrine (*A. rigida* Mill. var. *sisalana* Engelm.)
Amaranthus paniculatus L. (*A. cruentus* L.)
Annona L. spp.
?arica papaya L.
Casimiroa edulis La Llave et Lex.
Chenopodium ambrosioides L.
Ch. nuttalliae Safford (*Ch. berlandieri* Moq. ssp. *nuttalliae* (Safford) Wilson et Heiser)
Crataegus mexicana Moçiño et Sessé ex DC.
Lucuma salicifolia H.B.K. (*Pouteria campechiana* (H.B.K.) Baehni)
Myrica mexicana Humb. et Bonpl. ex Willd.
Spondias mombin L.
S. purpurea L.
Tigridia pavonia (L. f.) Ker-Gawl.

V.2. South America (Andes)

Cultivated species strictly endemic to the given area, having their origin from wild species in that area

Chenopodium pallidicaule Aellen
Ch. quinoa Willd.
Oxalis tuberosa Molina
Tropaeolum tuberosum Ruiz et Pavón
Ullucus tuberosus Lozano

Cultivated species having their primary centres of origin or their most important secondary centres of origin in the area, or are represented by endemic taxa

Acca sellowiana (O. Berg) Burret
Ananas comosus (L.) Merrill
Arachis hypogaea L.
Capsicum annuum L.
Cucurbita maxima Duch.
C. mixta Pang. (*C. argyrosperma* Huber)
C. moschata Duch.
C. pepo L.
Gonolobus edulis Hemsl.
Gossypium barbadense L.
G. hirsutum L.
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.
Ipomoea batatas (L.) Lam.
Lycopersicon esculentum Mill.
Manihot esculenta Crantz
Nicotiana rustica L.
N. tabacum L.
Parthenium argentatum A. Gray
Persea americana Mill.
Phaseolus acutifolius A. Gray
Ph. lunatus L.
Ph. multiflorus Lam. (*Ph. coccineus* L. ssp. *coccineus*)
Ph. vulgaris L.
Rauvolfia canescens L.
Sechium tacaco (Pittier) C. Jeffrey (*Polakowskia tacaco* Pittier)
Smallanthus sonchifolius (Poepp. et Endl.) H. Robins.
Solanum andigenum Juz. et Buk. (*S. tuberosum* L. ssp. *andigena* (Juz. et Buk.) Hawkes)
S. muricatum Ait.
S. quitoense Lam.
S. tuberosum L.
Theobroma cacao L.
Vanilla planifolia Andr.

Appendix 2: Inventory of plants in the dependent areas of historical development of the flora of cultivated plants

A. Ethiopia and adjacent countries

Genera which include cultivated species, and cultivated species of Ancient Mediterranean origin

Avena abyssinica Hochst.
A. vaviloviana (Malz.) Mordv.
Brassica carinata A.Braun
Carum copticum (L.) Benth. (*Trachyspermum ammi* (L.) Sprague ex Turrill)
Cicer L.
Coriandrum L.
Crambe L.
Hordeum L.
Lactuca L.
Lathyrus L.
Lens Mill.
Linum L.
Lupinus albus L.
Olea L.
Pisum L.
Trigonella foenum-graecum L.
Triticum aestivum L.
T. aethiopicum Jakubz. (*T. turgidum* L. ssp. *abyssinicum* Vavilov, *T. durum* L. ssp. *abyssinicum* Vavilov)
T. dicoccon Schrank (*T. turgidum* L. ssp. *dicoccon* (Schrank) Thell.)
T. polonicum L. (*T. turgidum* L. ssp. *polonicum* (L.) Thell.)
Vicia faba L.

Cultivated species of African origin

Catha edulis (Vahl) Forssk. ex Endl. [indigenous crop in Ethiopia and Yemen]
?offea arabica L.
?oleus edulis Vatke (*Plectranthus edulis* (Vatke) Agnew)
C. igniarius Schweinf.
C. lanuginosus Hochst.
C. penzigii Schweinf.
Commiphora myrrha (Nees) Engl.
Dolichos lablab L. (*Lablab purpureus* (L.) Sweet)
Eragrostis tef (Zuccagni) Trotter
Gossypium herbaceum L.
Guizotia abyssinica (L. f.) Cass.
Mimusops laurifolia (Forssk.) Friis
Pennisetum americanum (L.) Schumann convar. *spicatum* (L.) Tzvel.
Sesamum L. spp.
Sorghum durra (Forssk.) Stapf ex Prain

B. Central and Northern Europe

Cultivated species of Ancient Mediterranean origin which developed local varieties and ecotypes in the area

?) from Anterior Asia
Cicer arietinum L.
Hordeum vulgare L.
Lathyrus sativus L.
Lens culinaris Medik.
Linum bienne Mill. (*L. usitatissimum* L. ssp. *angustifolium* (Huds.) Thell.)
L. crepitans (Boenningh.) Dum. (*L. usitatissimum* L. convar. *crepitans* (Boenningh.) Kulpa et Danert)
Melo cantalupa Pangalo (*Cucumis melo* L. var. *cantalupensis* Naud.
Pisum sativum L.
Secale cereale L.
Triticum aestivum L.
T. dicoccon Schrank (*T. turgidum* L. ssp. *dicoccon* (Schrank) Thell.)
T. monococcum L.

b) from the Mediterranean
Beta vulgaris L.
Cynara cardunculus L.
Lavandula L. spp.
[And also many large seed and large fruit forms of cereals, legumes, fruits and other plants of the Mediterranean.]

Cultivated species of East Asian origin
Armeniaca vulgaris Lam.
Panicum miliaceum L.

Cultivated species of New World origin
Capsicum annuum L.
Lycopersicon esculentum Mill.
Nicotiana tabacum L.
Solanum tuberosum L.
Zea mays L.

Indigenous crops of the area
Allium ursinum L.
Antirrhinum majus L.
Armoracia rusticana P. Gaertn.
Brassica campestris L.
B. napobrassica (L.) Mill. (*B. napus* L. ssp. *napobrassica* (L.) Hanelt)
B. napus L.
B. oleracea L.
B. rapa L.

Carum carvi L.
Crambe maritima L.
C. tatarica Sebeok
Dactylis polygama Horvátovszky
Daucus carota L. ssp. *occidentalis* Rubasch. (*D. carota* L. ssp. *sativus* (Hoffm.) Schübl. et Mart.)
Digitalis purpurea L.
Grossularia reclinata (L.) Mill.
Lolium multiflorum Lam.
L. perenne L.
Mentha crispa L.
M. longifolia (L.) L.
M. spicata L.
M. ×*piperita* L.
Onobrychis viciifolia Scop.
Ornithopus perpusillus L.
O. sativus Brot.
Pastinaca sativa L.
Raphanus sativus L.
Ribes nigrum L.
R. rubrum L.
R. uva-crispa L.
Rumex acetosa L.
R. arifolius All.
R. scutatus L.
Scopolia carniolica Jacq.
Trifolium expansum Waldst. et Kit.
T. hybridum L.

C. The Russian Plain

Cultivated species which developed local varieties and ecotypes in the area

Ancient Mediterranean origin

Avena sativa L.
Beta vulgaris L.
Brassica capitata (L.) Pers. (*B. oleracea* L. var. *capitata* L.)
B. juncea (L.) Czern.
B. rapoeuropaea Sinskaya (*B. rapa* L. ssp. *rapa*)
Camelina sativa (L.) Crantz
Coriandrum sativum L.
Hordeum vulgare L.
Lens culinaris Medik.
Linum usitatissimum L.
Pisum sativum L.
Secale cereale L.
Trifolium pratense L.

Triticum aestivum L.
T. dicoccon Schrank (*T. turgidum* L. ssp. *dicoccon* (Schrank) Thell.)
T. durum Desf. (*T. turgidum* L. ssp. *durum* (Desf.) Husn.)
Vicia faba L.
V. sativa L.

East Asian origin

Armeniaca vulgaris Lam.
Panicum miliaceum L.

South Asian origin

Cucumis sativus L.
Fagopyrum esculentum Moench

New World origin

Capsicum annuum L.
Helianthus annuus L.
Lycopersicon esculentum Mill.
Nicotiana rustica L.
N. tabacum L.
Solanum melongena L.
S. tuberosum L.
Zea mays L.

Indigenous crops of the area

Agrostis gigantea Roth
Alopecurus pratensis L.
Amoracia rusticana P. Gaertn.
Apocynum sibiricum (Pall.) Russan
Beckmannia Host
Brassica napobrassica Mill. (*B. napus* L. ssp. *napobrassica* (L.) Hanelt)
Bromopsis inermis (Leys.) Holub (*Bromus inermis* Leys.)
Dactylis glomerata L.
Euonymus verrucosus Scop.
Festuca pratensis Huds.
F. rubra L.
Malus praecox (Pall.) Borkh. (*M. sylvestris* (L.) Mill. var. *praecox* (Pallas) Ponomar.)
M. sylvestris (L.) Mill.
Medicago borealis Grossh.
M. falcata L. s.l.
Melilotus alba Medik.
Onobrychis arenaria (Kit. ex Willd.) DC.
O. tanaitica Spreng.
Phleum pratense L.
Poa palustris L.
P. pratensis L.
Prunus fruticosa Pall.

Pyrus communis L.
Trachomitum sarmatiense Woodson
Trifolium hybridum L.
T. pratense L. s.l.
T. repens L.

D. Siberia and Far Eastern Russia

Cultivated species which developed local varieties and ecotypes in the area

Ancient Mediterranean origin

Avena sativa L.
Brassica rapa L.
Coriandrum sativum L.
Hordeum vulgare L.
Secale cereale L.
Triticum aestivum L.

East Asian origin

Brassica juncea (L.) Czern.
Echinochloa frumentacea Link
Glycine max (L.) Merr.
Oryza sativa L.
Panicum miliaceum L.
Raphanus sinensis Sinskaya (*R. sativus* L. ssp. *sinensis* Sazon. et Stankev.)

South Asian origin

Fagopyrum esculentum Moench

Indigenous crops of the area

Actinidia arguta (Siebold et Zucc.) J.E. Planch. ex Miq.
A. kolomicta (Maxim.) Maxim.
?donis L.
Agropyron cristatum (L.) Gaertn.
A. desertorum (Fisch. ex Link) Schult.
A. sibiricum (Willd.) Beauv.
Alopecurus pratensis L.
Armeniaca sibirica (L.) Lam.
Bergenia crassifolia (L.) Fritsch
Bromopsis inermis (Leys.) Holub (=*Bromus inermis* Leys.)
B. karavajevii (Tzvel.) Czer. (*B. pumpelliana* (Scrib.) Holub ssp. *karavajevii* (Tzvel.) Tzvel.)
B. pumpelliana (Scrib.) Holub (*B. pumpellianus* Scrib.)
Camelina sativa (L.) Crantz
Dactylis glomerata L.
Elymus sibiricus L.
E. trachycaulus (Link) Gould et Shinners
Euonymus maackii Rupr.

Festuca pratensis Huds.
Heracleum dissectum Ledeb.
H. lanatum Michx.
H. sibiricum L.
Hippophae rhamnoides L.
Malus baccata (L.) Borkh.
Medicago falcata L. (*M. sativa* L. ssp. *falcata*)
Melilotus alba Medik.
Onobrychis arenaria (Kit.) DC. ex Willd.
O. sibirica Turcz.
O. tanaitica Spreng.
??? L.
Pyrus ussuriensis Maxim.
Ribes hispidulum (Jancz.) Pojark. (*R. spicatum* Robs. ssp. *hispidulum* (Jancz.) Hamet-Ahti)
R. nigrum L.
R. rubrum L.
Schisandra chinensis (Turcz.) Baill.
Vicia amoena Fisch. ex DC.
Vitis amurensis Rupr.

E. North America

Indigenous crops of the area

Apocynum cannabinum L.
?arya illinoinensis (Wagenh.) K. Koch
Claytonia perfoliata Donn.
Cucurbita pepo L.
Fragaria platypetala Rydb. (*F. virginiana* Mill. ssp. *platypetala* (Rydb.) Staudt)
F. virginiana Mill.
Grossularia cynosbati (L.) Mill. (*Ribes cynosbati* L.)
G. divaricata (Dougl.) Cov. et Britt. (*Ribes divaricatum* Dougl.)
G. hirtella (Michx.) Spach (*Ribes hirtellum* Michx.)
G. nivea (Lindl.) Spach (*Ribes niveum* Lindl.)
G. oxyacanthoides (L.) Mill. (*Ribes oxyacanthoides* L.)
Helianthus annuus L.
H. tuberosus L.
Juglans cinerea L.
J. nigra L.
Lewisia rediviva Pursh
Lupinus polyphyllus Lindl.
Malus fusca (Raf.) C. Schneider
M. rivularis Roem.
Montia perfoliata (Donn) Howell (*Claytonia perfoliata* Donn)
Prunus americana Marsh.
Rubus flagellaris Willd.
R. idaeus L.
R. × *loganobaccus* Bailey

R. macropetalus Dougl. ex Hook.
R. titanus Bailey
R. vitifolius Cham. et Schlecht.

Appendix 3: Inventory of cultivated plants of Egypt

Indigenous crops of the area

Apium graveolens L.
Cyperus esculentus L.
C. papyrus L.
Eragrostis cynosuroides Beauv.
Lupinus albus L.
Nelumbo nucifera Gaertn.
Nymphaea lotus L.

Cultivated plants introduced into Egypt, which developed endemic forms and varieties there

Allium cepa L.
A. porrum L.
A. sativum L.
Beta orientalis Roth (*B. vulgaris* L. ssp. *maritima* (L.) Arcang.)
Cajanus cajan (L.) Millsp.
Carthamus tinctorius L.
?itrullus lanatus (Thunb.) Matsum. et Nakai
Commiphora myrrha (Nees) Engl.
?oriandrum sativum L.
?rocus sativus L.
Cucumis sativus L.
Cynara scolymus L.
Ficus carica L.
Foeniculum vulgare Mill.
Gossypium hirsutum L.
Hordeum vulgare L.
Lagenaria siceraria (Molina) Standl.
Lathyrus sativus L.
Lens culinaris Medik.
Linum usitatissimum L.
Lupinus albus L.
Melo Mill. emend. Pang.
Mimusops laurifolia (Forssk.) Friis
Olea europaea L.
Panicum miliaceum L.
Papaver somniferum L.
Phoenix dactylifera L.
Pimpinella anisum L.
Pisum sativum L.
Portulaca oleracea L.

Punica granatum L.
Raphanus sativus L.
Ricinus microcarpus Popov (*R. communis* L.)
Sesamum indicum L.
Setaria italica (L.) Beauv.
Sorghum durra (Forssk.) Stapf ex Prain
S. sudanense (Piper) Stapf ex Prain
Trifolium alexandrinum L.
T. resupinatum L.
Triticum aethiopicum Jakubz. (*T. turgidum* L. ssp. *durum* (Desf.) Husn.) [archaeological plant remains]
T. compactum Host [archaeological plant remains]
T. dicoccon Schrank
T. durum Desf. (*T. turgidum* L. ssp. *dicoccon* (Schrank) Thell.)
T. monococcum L.
Vicia faba L.
Vigna sinensis (L.) Hassk. (*V. unguiculata* (L.) Walp. ssp. *unguiculata*)
Vitis vinifera L.

Evaluation of pod, seed, and phenological traits of standard genebank accessions of common bean (*Phaseolus vulgaris* L.) over a period of eight years

U. FREYTAG [1], G.H. BUCK-SORLIN [2] and B. SCHMIDT [1]

Abstract

Six standard genebank accessions of common bean (*Phaseolus vulgaris* L.) were cultivated over a period of eight years (1993-2000) within the frame of a long-term field trial at the IPK in Gatersleben. Morphological and phenological traits were assessed routinely in the field every year; additionally, typical pods and seeds of each accession and year were documented as digital images and further traits automatically measured using a digital image analysis system (DIAS). Using such a DIAS (the software QWin in this case), it is possible to rapidly capture pod and seed features that are normally difficult or impossible to measure otherwise (e.g., roundness of shape, circumference). Analysis of Variance of all traits measured, carried out for the factors genotype as well as temperature, precipitation, air humidity for the vegetation months May to August of each year, yielded a very diverse picture: whereas, e.g., the variation in most seed-related traits appeared to be due to the factor genotype (especially Thousand-Grain-Weight), the variance observed in the duration of the vegetation period or germination rate exhibited a complicated network of, sometimes contrasting, microclimatic factors. The findings of this study are discussed in connection with their consequences for the evaluation of trait data for taxonomic and genebank work.

Introduction

The accurate characterisation of genebank accessions of a crop species under consideration of all available morphological, phenological, and molecular information is the basis of every sensible breeding programme. However, in carrying out such investigations, the climate-related variability of certain traits relevant to breeding is un-

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derestimated. Evaluation data collected in this connection often will not be analysed or merely serve for an internal judgement of the samples. Here we try, on the basis of a permanent cultivation over eight years, to quantify the influence of microclimate on morphological and phenological traits in bean using six standard accessions of the genebank Gatersleben. Using digital image analysis, we attempted to introduce at the same time the capture of biometric (length, diameter etc.) as well as hitherto unused traits (e.g., roundness of the seed or pod). This approach has been introduced recently for the additional characterisation of genebank material and in taxonomy and has already been successfully applied to bean seeds (e.g. VAN DER HEIJDEN 1998, 1990).

Complete linkage maps exist for the common bean (FREYRE et al. 1998), and marker-based analyses of morphological and agronomic traits have been carried out in the recent past (SINGH et al. 1991). Some morphological traits, such as pod tip orientation, have been said to be due to the effect of one gene only, which, on the basis of our study, appears at least doubtful (for a taxonomic classification of the bean based on pod and seed shape, see the very nice monograph by ROMERO 1961). Among the studies dealing with the morphological and phenological variability of the common bean (*Phaseolus vulgaris* L.), there is none that treats the longer-term cultivation of a set of standard accessions. Therefore, in this study, an 8-year cultivation trial was carried out, in order to find stable taxonomic characters that are not or only minimally influenced by climatic factors.

Material

Six standard genebank accessions of common bean (*Phaseolus vulgaris* L.) were cultivated in the field in Gatersleben from 1993 to 2000. Analysed were the following data:

- Assessment of field cultivations from 1994 to 2000.
- Germinability tests and Thousand-Grain-Weight of samples held in cold storage.
- Pod measurements from the cultivation 1994 to 2000.
- Seed measurements from the cultivation 1993 to 2000.

Five bush bean cultivars (*P. vulgaris* ssp. *vulgaris* var. *nanus* (Jusl.) Aschers.) and one stringbean cultivar (*P. vulgaris* ssp. *vulgaris* var. *vulgaris* syn. *Phaseolus ritensis* M.E. Jones) from the Gatersleben genebank collection were used:

1) PHA 6017: var. *nanus* 'Imuna': Virides without strings, medium early, pod length about 12 cm, rounded narrow, fleshy, straight. Seed white, cylindrical, weakly kidney-shaped, slow-maturing; released 1972 in France.

2) PHA 6018: var. *nanus* ‘Michelite’: Virides with strings; qualified cultivar in France and the Netherlands.
3) PHA 6019: var. *nanus* ‘Redlands Greenleaf B’: Virides with strings.
4) PHA 6020: var. *nanus* ‘Dubbele Witte’: Virides with strings; pods 10-12 cm long, narrow to medium broad, flat oval, seed locations clearly marked, weakly to medium bending; pod whitish-green, seed very full, white to greyish-white, often with brown spots.
5) PHA 6021: var. *vulgaris* ‘Great Northern U.I. 31’. Virides with strings.
6) PHA 6022: var. *nanus* ‘Pinto 114’: Virides without strings.

Cultivation – growing conditions

Germination in bean takes places within a temperature frame of 10 to 37°C. Planting seeds outdoors can be done only when the medium daily temperature is 12-18°C (which is the case in Gatersleben at the beginning of May). Seedling emergence in the field requires, along with a soil temperature of at least 9°C, 7-14 days of 10-14°C air temperature. This ensures good seed maturity, which is particularly important for a genebank.

The cultivation period (date of planting seeds to last harvest date) was between 106 and 159 days in *Phaseolus vulgaris*, depending on year and accession. Favourable for seed production is a dry climate; wind exposure, on the other hand, is unsuitable for bean cultivation, since, due to strong air movements, shoots are rubbed against each other and damaged, which often is followed by infections.

Planting dates ranged between 5 May and 9 May, flowering dates between 18 June and 29 July, and harvest dates between 19 August and 12 October. Harvest was carried out on several occasions per accession.

Assessment of diseases (Viruses, halo blight, alfalfa mosaic virus) was done during 1993 and 1994 in all accessions. Degree of infestation was assessed as “few halo spots” and “few viruses”.

All accessions of the genebank were botanically identified in the field and assessed for the traits growth form, background pod colour, strings, standard pod colour, pod form, flowering date, flower colour, date of maturity, diseases, seed size, seed form, and seed colour. Additionally, agronomical traits were captured. These data were registered in a FoxPro database table.

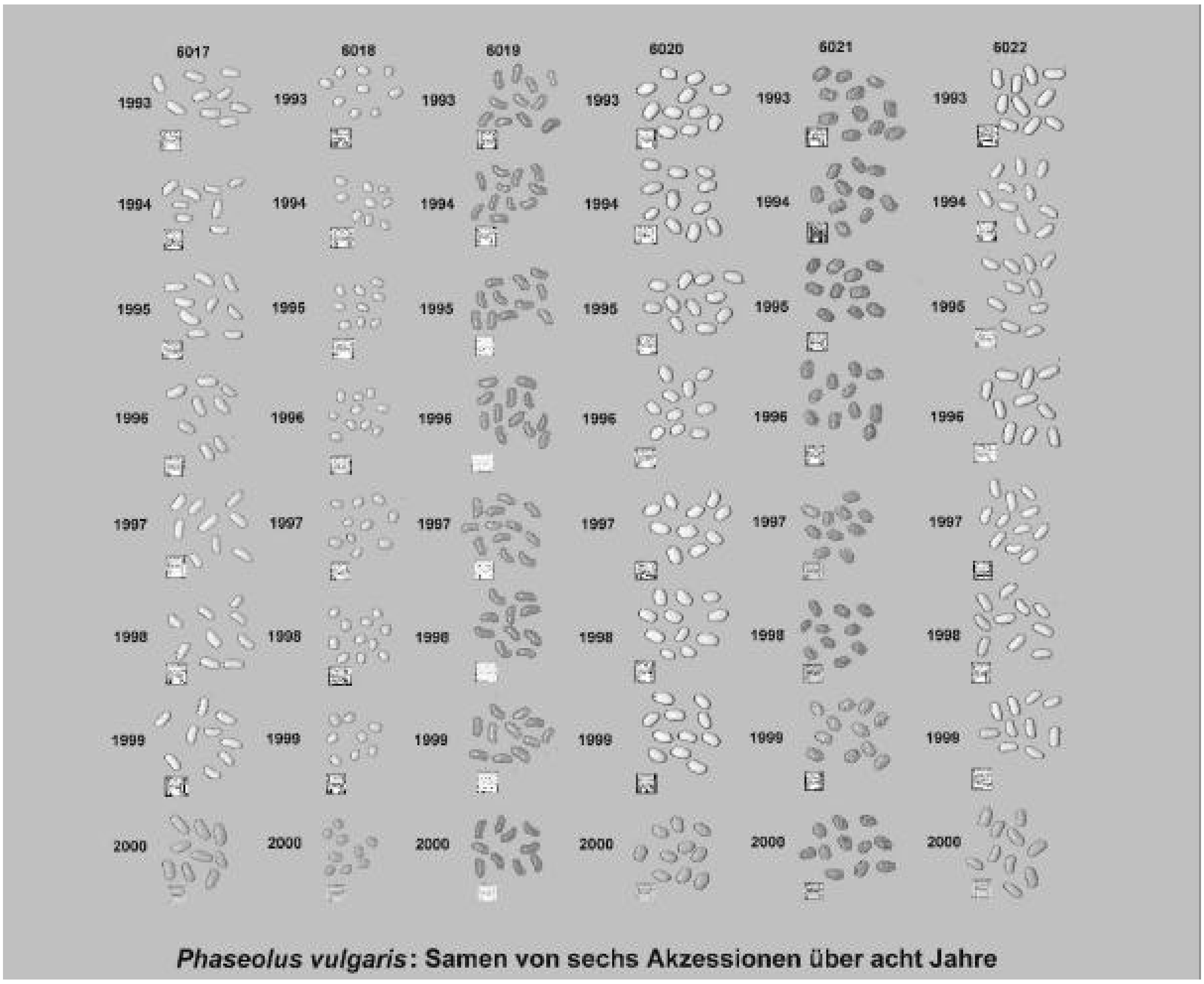


Fig.1: ***Phaseolus vulgaris*** **- Seeds from six accession about eight years**

Post-harvest treatment and seed storage in the cold depository

Before depositing the seeds in the cold storage facility, they were dried in a separate room for 20 days at 20% humidity and a temperature of 20℃. Thus, a moisture content of 5-6% was achieved. Storage succeeded stepwise in cold chambers at 0℃ and –15℃, from 2001 on at –15℃ in 1-litre preserving jars with an addition of 160g silica gel per jar.

Thousand grain weight

Thousand Grain Weight was measured using the computer software WIN-TKG and stored directly on a PC. In doing so, the PC was connected via a serial interface to an electronic scale, which measured the weight of the seeds after counting using a seed counting machine.

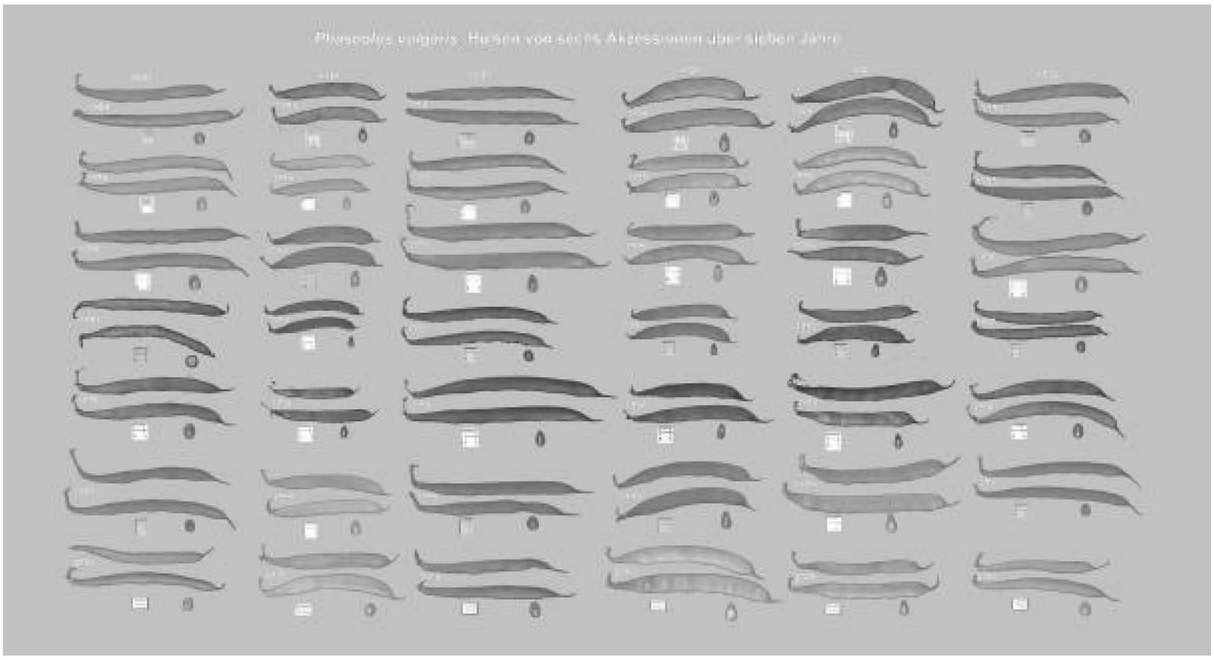
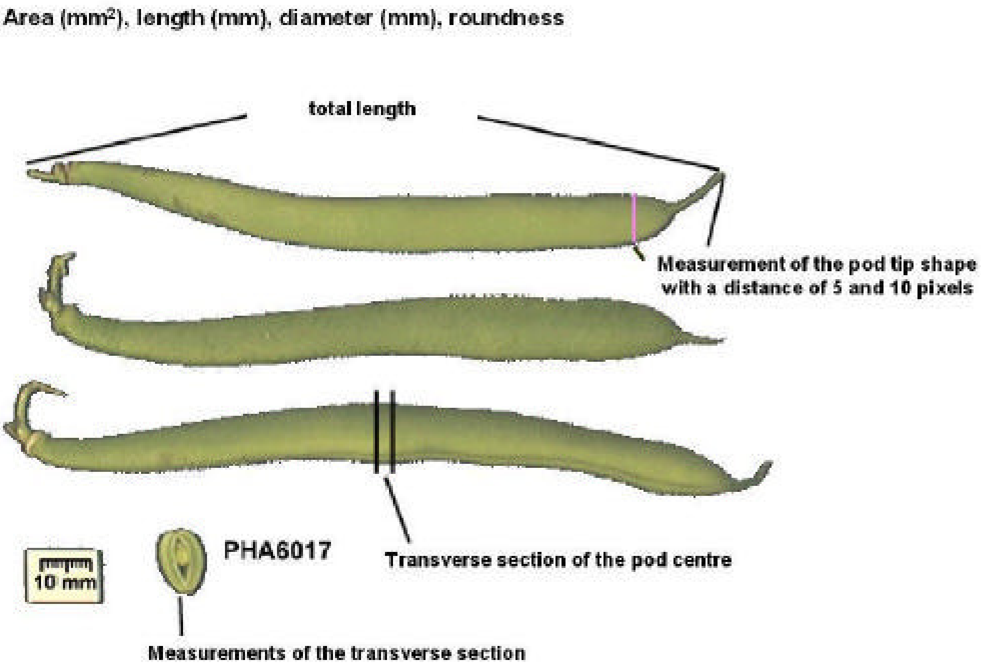


Fig. 2:Phaseolus vulgaris – Pods from six accession about seven years

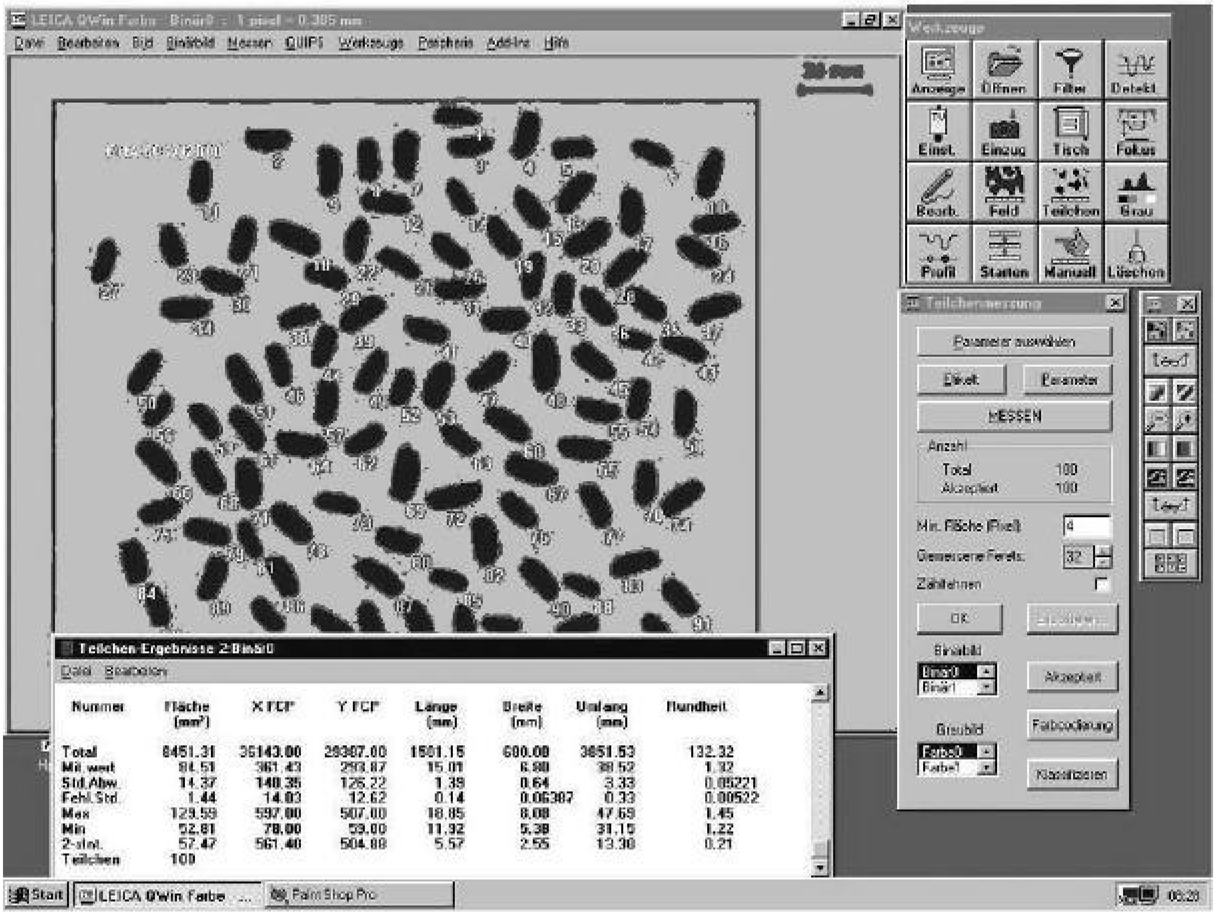
Fig. 3: Measurements on a digital image of the pod



Germinability

Tests of germinability followed the "International Regulations for Seed Testing" (ISTA 1999). Depending on size and number of available seeds, 50 to 100 seeds are set up in germination rolls (substrate: moistured filter paper) in a germination bank. Seeds are germinated between two layers of paper at 20 °C room temperature. First counts are carried out after five days, final counts after nine days. Analysed are healthy, germinable seeds, hard and fresh seeds, as well as abnormal and rotting seeds. The computed germinability in per cent is derived from the number of healthy and germinable seeds.

Fig. 4: Seed measurements and statistical analysis



Anzahl
Total 100
Akzeptiert 100
Min. Fläche (Pixel) 4
Gemessene Ferets: 32
Zählrahmen ☐
Binärbild: Binär0
Graubild: Farbe0

```
Nummer      Fläche     X FCP      Y FCP      Länge     Breite     Umfang     Rundheit
            (mm²)                            (mm)      (mm)       (mm)

Total       8451.31    36143.00   29307.00   1501.15   600.00     3851.53    132.32
Mit.wert      84.51      361.43     293.07     15.01     6.00       38.52      1.32
Std.Abw.      14.37      140.35     126.22      1.39     0.64        3.33      0.05221
Fehl.Std.      1.44       14.03      12.62      0.14     0.06387     0.33      0.00522
Max          129.59      597.00     507.00     18.85     8.08       47.69      1.45
Min           52.81       78.00      59.00     11.32     5.38       31.15      1.22
2-sint.       57.47      561.40     504.88      5.57     2.55       13.30      0.21
Teilchen     100
```

Measurements on pods and seeds

Figs. 1 and 2 show the range of variation of the accessions investigated. In order to carry out measurements on pods (Fig. 3) and seeds (Fig. 4), the PC software QWin and a 3CCD Colour Video Camera connected to the PC were employed. This type of image analysis allows the determination of geometrical and greyscale values from digital images of arbitrary sources. Each of 100 seeds, pods and pod transverse sections as well as the curvature of the pod tips were measured with distances of 10 pixels horizontally and 5 pixels vertically.

Analysed per accession and year were: area (mm^2), length (mm), diameter (mm), circumference (mm) and roundness (roundness is a factor which for a circle adopts its smallest value of 1. It corresponds to the square of an object's circumference, divided by its area).

Statistical analysis

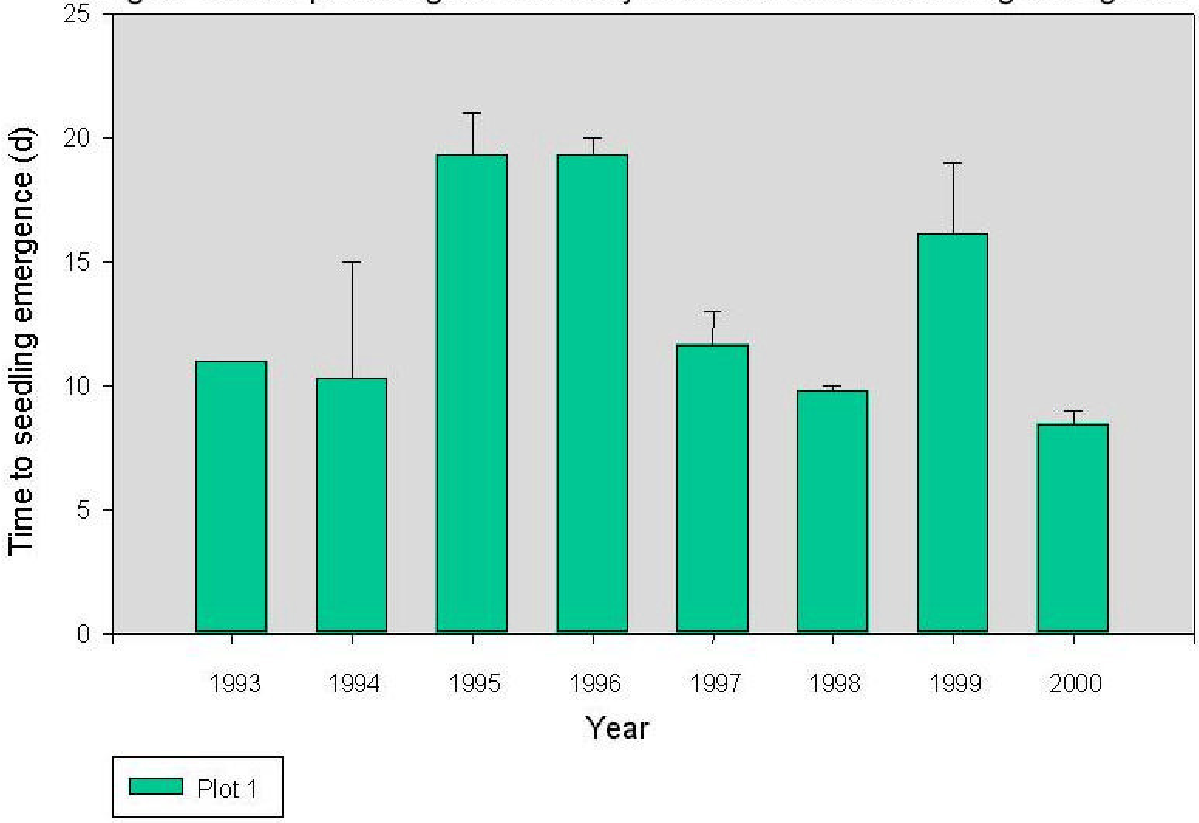
Phenological as well as biometrical data (the latter gathered automatically through digital image analysis) were stored in MS Excel files and analysed statistically as appropriate using the software MINITAB (version 12.1 for Windows). Here, the functions Describe, Oneway, Twoway, GLM, Regress, % Fitline, and Correlation of MINITAB were employed to compute means and standard deviations for the parameters measured and to carry out analyses of variance, correlations and regressions.

Results and discussion

Phenological traits and image analysis

Of all phenological traits, the time to flowering (TTF), the time to maturity (TTM) and the net growth time (NGT) significantly depended upon the genotype (accession), whereas the germinability (GERM), the duration of cultivation (TV), and the time to seed emergence (EMERG) were all independent of the genotype but exhibited heavy fluctuations among the different years (especially EMERG where the complete variability was annual: Figure 5). The data that were gained by image analysis (area, length, diameter, circumference, roundness of seeds, pods, and pod transverse sections) conveyed a different picture: Whereas the seed characters were all strongly genotype-specific (only about 5% annual variability), the annual variability of the pod transverse section parameters amounted to about 35%. The situation was unclear as regards the pod characters: although the percentage of the annual variability lay between 19 and 69% according to the nested analysis of variance, all pod characters differed significantly only among the accessions. This shows that the choice of accessions can have a strong influence upon the analysability of climate data: morphologically strongly deviating genotypes are masking a relatively weaker but actually clear climatically related variability.

Fig. 5: Annual phenological variability in beans: time to seedling emergence



Germination

The factor year had a significant influence on germination: Almost 83% of the variability in germination rate was directly related to the factor year. Genotype, on the other hand, had no significant effect on germination. Low temperatures in May (2 m above soil surface) increased germinability, whereas temperatures in June and July did not have any effect on germination rate. Surprisingly, low August temperatures were connected to a low germination rate, whereas the opposite was true for high and normal August temperatures.

Neither the amount of precipitation in every month nor air humidity had a significant effect on germination. Averaged over the entire cultivation period (May to August), there was no significant effect of the three factors temperature, precipitation and air humidity, on germination.

Thousand Grain Weight

The accession PHA 6018 exhibited a significantly lower Thousand Grain Weight than all other accessions. However, the factor year had no significant effect on Thousand Grain Weight.

Duration of cultivation

Whereas the genotype had no significant influence on the duration of cultivation, the effect of the year was considerable. The temperature of all months except May, had a significant effect on the length of the cultivation period: High and normal temperatures in June led to a prolongation, whereas high July temperatures decreased the cultivation period; a deviation from normality of August temperatures always led to an increase of the cultivation period. A dry May decreased cultivation period, while rain in June had no significant effect on the cultivation period. On the other hand, high precipitation in July and August considerably prolonged the cultivation period. The effect of relative air humidity on the cultivation period gained in significance with increasing duration of the cultivation period: a high humidity in June decreased the cultivation period, whereas the opposite effect was observed (i.e., a prolongation of the cultivation period) for high humidity in July and August.

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Genetic resources in strawberries in Europe [1]

M. GEIBEL [2]

In 1994 and 1995 an initial inventory of the main European collections was completed with 900 strawberry cultivars being identified in the collections. In 1998 the European COST action 836 “Integrated Research in Berries” was started to coordinate the scientific activities in 20 partner countries. The first overview of the working group responsible for genetic resources has shown that the collections maintained by the participating institutes have changed significantly within these few years. In 18 institutes 2,747 cultivar accessions and 463 wild species accessions are preserved. Nearly half of the 928 listed cultivars are grown only at one site and four important old cultivars seem to have been lost. Subsequently, 106 cultivars were selected to be maintained in a core collection based on historical significance or due to the expression of important traits. The participants of the working group have agreed on a memorandum of responsibility to preserve mainly the core collection in at least two different locations. The results of the planned evaluation at the different institutions should result in a future European *Fragaria* database.

Reference

GEIBEL, M. (2002): Genetic Resources in Strawberries in Europe. - Acta Horticulturae **567**, 73-75. (3rd International Strawberry Symposium, Tampere, 2000).

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[1] This presentation is a summary of a paper accepted for publication in the journal Acta Horticulturae

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Tab. 1: Actual European strawberry collections

Place	**Country**	**Curator**	**Wild-species**	**Cultivars**		**Responsibility**		
			accessions	total	core	total	core	planned*
Piikkiö	FIN	Tarja Hietaranta	1	149	25	13	9	-
Stjordal	NOR	Jahn Davik	0	103	10	-	-	-
Balsgård	SWE	Karin Trajkovski	69	124	17	16	10	7
East Malling	GBR	David Simpson	20	240	43	28	28	4
Wageningen	NLD	Bert Meulenbroek	0	84	19	10	10	1
Balandran	FRA	Jean Claude Navatel	0	171	31	6	6	-
Bergerac, Ciref	FRA	Philippe Roudeillac	35	223	45	35	35	6
Wurzen	DEU	Erik Schulte	3	236	30	6	6	-
Pillnitz, BAZ	DEU	Barbara Dathe	34	116	23	3	2	13
Pillnitz, IPK	DEU	Martin Geibel	174	275	57	143	44	22
Skierniewice	POL	Edward Zurawicz	1	105	10	2	2	2
Cluj-Napoca	ROM	Nelu Orlaie	1	137	25	10	10	2
Pitesti	ROM	Mihail Coman	12	170	29	9	4	-
Kostinbrod	BGR	Violeta Kondakova	5	188	36	8	8	1
Ancona	ITA	Bruno Mezetti	18	-	-	-	-	-
Cesena	ITA	Walther Faedi	1	94	7	1	1	-
Roma	ITA	Walther Faedi	0	137	13	5	5	1
Málaga	ESP	Juan F. Sánchez Sevilla	89	195	16	9	9	-
total no. cultivars				**928**	**106**	**213**	**100**	**59**
total no. accessions			**463**	**2,747**	**442**	**304**	**189**	

*responsibility after addition of the cultivar to the own collection

Genetic improvement in grain yield, yield components and agronomic traits of spring barley (*Hordeum vulgare* L.)

H. GRAUSGRUBER, H. BOINTNER, R. TUMPOLD and P. RUCKENBAUER [1]

Introduction

Barley breeding in Austria started with the selection of Bohemian and Moravian landraces for improved malting quality. Around 1875, E. V. PROSKOWETZ became aware of the excellent malting quality of the barleys from the Moravian *Hanna* region and started ear selection. In 1903, E. V. TSCHERMAK combined the best lines into the so-called 'Kwassitzer Original Hanna Pedigree Gerste'. Because of its excellent malting quality this cultivar was distributed in Austria, Czechoslovakia, Germany, Sweden and America, and was intensively used by breeders for hybridisation. Tschermak's cross with a barley from Anatolia resulted in the cultivar 'Hanna-Kargyn', which won the first prize at the international malting barley exhibition in 1927 in London. In the 1930s and 1940s, 'Vollkorn' barleys, selections from 'Kneifel', dominated. Breeding was still done by ear selection of landraces and/or hybridisation between them. Until 1948, no foreign spring barley was registered in Austria. However, in the 1950s Danish ('Carlsberg II'), Swedish ('Weibulls Rika', 'Weibulls Herta') and German cultivars ('Heines Haisa', 'Firlbecks Union') replaced Austrian selections because of their higher yields and better straw stiffness. The percentage of Austrian cultivars decreased to 5% of the seed market. This dramatic fall led to an intensification of the activities of Austrian barley breeders and to the beginning of carefully directed hybridisation and breeding programmes both for the Pannonic and the Baltic climate

Tab. 1: Investigated spring barleys and their main growing period

Growing period	Barley cultivars
before 1900	*Nürnberg 1, Nürnberg 2, 1877/12, 1877/27, 1877/31*
1900-1930	'Tschermaks Hanna-Kargyn', 'Kneifel', *Tuxer*
1930-1960	'Vollkorn', 'Angerner früh', *Tschermaks glattgrannige zweizeilige,* 'Fisser Imperial', 'Haisa'
1960-1980	'Liechtenstein', 'Union', 'Martha', 'Eura II', 'Adora'
1980-2000	'Berta', 'Ebra', 'Viva 1', 'Elisa', 'Prosa', 'Penelope'

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zone. As a result of these efforts Austrian spring barley cultivars were successfully registered also in other European countries in the last decades.

In this study the genetic improvement in grain yield, yield components and agronomic traits was determined over three seasons under the low-rainfall conditions of the Pannonic climate zone.

Materials and methods

Experiments involving 24 genotypes (Tab. 1) were carried out over three seasons (1999-2001). In seven trials the increase in grain yield, yield components and agronomic traits achieved by barley breeding during the period of 1832 to 1996 was estimated. The field trials were carried out in Groß Enzersdorf, Raasdorf and Vienna under natural conditions. No fungicides were applied to control diseases, and tall genotypes were not supported in order to prevent yield losses.

Diseases, time to heading and plant height were recorded during the vegetation period. From three trials, 10 to 15 single plants from inside the plots were analysed for the yield components number of spikes per plant, number of kernels per spike and thousand kernel weight (TKW). In four trials kernel number per square meter (KN) was deduced from the relationship between grain yield (GY) and the yield components: GY = KN * TKW. Subsequently the number of kernels per plant and yield per plant was deduced from the germinated seeds per square meter. Harvested grains were analysed for test weight and % protein and % malt extract (fine grind). The latter quality traits were determined using NIRS. An overall resistance score was calculated according to OBERFORSTER (1997), however, modified in a way that the score was calculated for each replicate and not over the replicates for the respective trials.

Results

No significant improvement over the period of more than 130 years was observed for time to heading and test weight. For the single yield components, genetic improvement was generally observed only since the 1960s (Tab. 2). Almost all cultivars which were originally selected for regions with higher rainfall, e.g., *Tuxer*, 'Fisser' and 'Martha', performed below the observed trends over time (Fig. 1a).

Correlation analyses between the yield components revealed for all three seasons that yield per plant was primarily a function of the number of spikes per plant, followed by TKW. The number of kernels per spike was only of less influence. Hence, the genetic improvement in grain yield was above all due to the ability of modern cultivars to produce more spikes per unit area.

Tab. 2: Overall means (n = 7) for grain yield, yield components and agronomic traits

Cultivar	KPP[1]	TKW	YPP	YLD	HGHT	RES	PROT	MALT
Nürnberg 1	64.2	42.9	2.7	390	73	29.3	13.9	76.1
Nürnberg 2	64	40.3	2.6	367.4	71.3	31.3	13.9	76
1877/12	61.5	43.8	2.7	382.9	67.3	41.4	13.6	75.8
1877/27	58	41.6	2.4	351.6	72.1	38.9	13.9	75.9
1877/31	55.9	39.7	2.2	329	73.8	40.9	13.9	75.6
Tuxer	43.6	35.4	1.5	230.3	79.7	33.6	14.4	75.4
‘Hanna-Kargyn’	56.8	42.5	2.4	353	71	36.0	13.7	76
‘Kneifel’	54.9	40.7	2.2	332.9	76.1	29.5	14.1	76.7
Tschermaks gg	53.6	43.6	2.3	335.8	77.2	26.6	14.5	75.6
‘Fisser’	46.1	42	1.9	273.6	83.9	34.6	15.5	73.8
‘Angerner früh’	60.5	41.9	2.5	370.6	74.1	24.4	14.5	76
‘Vollkorn’	62.5	43.1	2.7	383.2	73	33	14	76.5
‘Haisa’	65.7	39.8	2.6	377.8	73.7	31	14.1	75.9
‘Liechtenstein’	61.9	41	2.5	367.3	65.9	30	12.8	77.3
‘Martha’	60.6	39.3	2.3	339.3	68.7	27.9	13.5	76.7
‘Eura II’	68	44.2	3	437	69.3	26.3	13.3	77
‘Union’	70.4	43.3	3	442.9	70.4	27.2	13.5	76.9
‘Adora’	71	41.2	2.9	421.9	64.7	19.4	12.7	77.7
‘Berta’	67.5	45.3	3	421.3	61.9	19.4	13.3	77.4
‘Ebra’	77	43.5	3.3	460	64.7	15.4	13.3	76.6
‘Viva 1’	66.1	41.6	2.7	417.3	59.1	19.5	12.8	78.1
‘Elisa’	77.7	48.8	3.7	505.6	66.4	11.9	13.3	77.5
‘Prosa’	76.9	45.4	3.5	465.6	58.3	20.2	12.6	78.3
‘Penelope’	64.7	45.3	2.9	406	60.9	17.8	13.7	77.7

[1] KPP, kernels per plant; TKW, thousand kernel weight (g); YPP, yield per plant (g); YLD, yield per m² (g); HGHT, height (cm); RES, resistance score; PROT, protein content (%); MALT, malt extract (%)

Besides the yield components significant genetic improvement was observed for plant height, resistance score (Fig. 1b) and % malt extract. For % protein the trend was less clear, however, malting barleys selected under Pannonic conditions, e.g., ‘Liechtenstein’, ‘Adora’, ‘Viva’, and ‘Prosa’, demonstrated their adaptability to the low rainfall conditions and exhibited the lowest protein content.

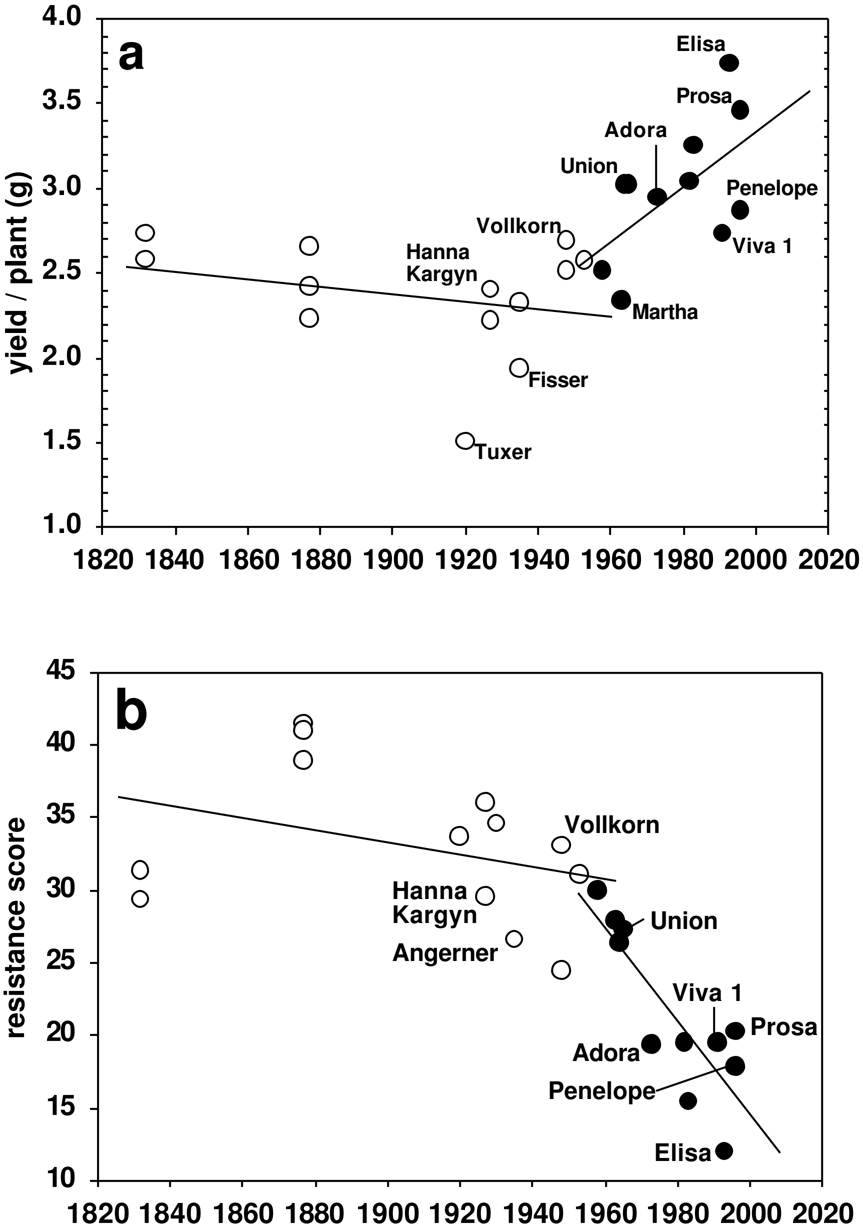

Fig. 1: **Improvement in (a) yield per plant, and (b) resistance score**
? land-races and cultivars released before 1958
? high bred cultivars released since 1958

Discussion

This study confirmed that the main genetic improvement in grain yield and agronomic traits of Austrian-grown barley cultivars began in the 1960s. A genetic improvement in yield of 0.8 to 1.2 % per year was estimated for the period of the last 40 years. These values are similar to those of EKMAN (1981), RGGS et al. (1981), HÄNSEL (1982) and MARTINIELLO et al. (1987).

The number of spikes per plant contributed most to the improvement in grain yield. This was also observed for Scottish (GYMER 1981), English (RIGGS et al. 1981) and American spring barleys (WYCH and RASMUSSON, 1983), as well as for Italian winter barleys (MARTINIELLO et al. 1987). BRETSCHNEIDER-HERRMANN and MALESEVIC (1976) stated that for grain yield the number of reproductive tillers is of greater importance in the case of barley than of wheat. The minor importance of the number of kernels per spike was also reported by GYMER (1981), RIGGS et al. (1981), WYCH and RASMUSSON (1983) and BULMAN et al. (1993).

Although modern cultivars performed best for all traits, some of the older cultivars and/or landraces could represent valuable genetic resources for breeding. Today the European barley market is dominated by only a few breeders located in the higher rainfall regions of northern and western Europe. This dominance could lead to genetic erosion within the European malting barley genepool resulting in cultivars which would be not adapted for the climatic conditions prevailing in eastern Austria. Hence, adapted landraces with other traits of interest, e.g., greater root systems, could be valuable crossing partners in breeding programmes for drought tolerance, nitrogen uptake efficiency and/or organic farming systems in order to maintain genetic diversity and variability for selection.

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Wild species as a source for introgression of interesting characters into crop plants - the case of *Allium*

E.R.J. KELLER [1], A. SENULA [1] and H. SCHULZ [2]

Abstract

A set of distant hybrids between various *Allium* species has been established in the recent years in the IPK genebank. It is interesting because of differences within the spectrum of sulphur compounds and aroma substances. The hybrids were produced by means of embryo rescue. Characteristic spectra of substances can be introduced by crossing from the parents to the hybrids. Susceptibility to virus infection, which is an important agricultural feature, is also species-specific. The differences can be recognized in hybrids as well.

Introduction

The genus *Allium* comprises several important species, which are used as vegetables and/or spices, such as onion and shallot (*Allium cepa* L.), leek (*A. ampeloprasum* L. s.l.), garlic (*A. sativum* L.), bunching onion (*A. fistulosum* L.), chives (*A. schoe noprasum* L.) and others. Nowadays, the medicinal application of *Allium* species becomes more and more evident. It is especially a group of sulphur compounds, the cysteine sulfoxides called alliin and its derivatives allicin, ajoen and several alk(en)yl(poly)sulfides, which are important. Furthermore, useful aroma substances are present. Amongst the sulphur compounds, but also within the aroma substances, some molecular species are more interesting than others. Therefore, the relative contents of the different fractions are of interest.

Crosses have been attempted between *Allium* species since 1935 (EMSWELLER and JONES 1935). So far, low crossability has been reported for species of this genus. Therefore, any novel crosses, in part facilitated by means of embryo rescue, are interesting for introgression of new characters into the main crop species. Besides disease resistance characters and plant structure and colour, the latter mainly interesting for ornamental breeding, product quality for food and medicinal uses are the main targets in species crosses of *Allium*.

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Some of the most famous hybrids have been produced between *Allium cepa* and *A. fistulosum*, others with *A. galanthum* Kar. and Kir., *A. pskemense* B. Fedtsch., *A. roylei* Stearn, *A. nutans* L., *A. chinense* G. Don, and *A. ampeloprasum* (Keller et al. 1996 Peterka et al. 1997). The situation within the Institute of Plant Genetics and Crop Plant Research (IPK) hosting the world's largest special collection of *Allium* (Fritsch 2001) encourages the direct utilisation of this broad diversity. Thus, own efforts were made between 1991 and 1993 to obtain hybrids with the help of *in vitro* embryo rescue. The hybrids have been included in the field and partly into the *in vitro* collection to be preserved for further utilisation. Recently, first steps were made to characterise these hybrids and to prepare some of them for further utilisation.

Results

Successful hybridisation of *Allium* species in the IPK Genebank

A. carolinianum DC. × *A. porrum* L.
A. cepa × *A. altaicum* Pall.
A. cepa × *A. angulosum* L.
A. cepa × *A. globosum* M.Bieb. *ex* Ried.
A. cepa × *A. karelinii* Poljak.
A. cepa × *A. obliquum* L.
A. cepa × *A. saxatile* M.Bieb.
A. cepa × *A. sphaerocephalon* L.
A. cepa × *A. albidum* Fisch. ex M.Bieb.
A. cepa × *A. altyncolicum* Friesen
A. cepa × *A. chevsuricum* Tscholok.
A. cepa × *A. hymenorrhizum* Ledeb.
A. cepa × *A. lineare* L.
A. cepa × *A. rubens* Schrad. ex Willd.
A. cepa × *A. senescens* L.
A. obliquum × *A. hymenorrhizum*

Biochemical hybrid analysis

As could be shown in some cases, the biochemical properties of the hybrids may possess intermediate heredity like many morphological characters (Schulz et al. 2000 a, b). Sometimes the contents of interesting compounds in the hybrid may be as high as in one of the parents. This is an encouraging finding for further studies to use hybrids directly as material for medicinal purposes.

Virus infection in *Allium* species and hybrids

The virus susceptibility and, therefore, the infection is different depending on the species. High virus susceptibility may be the cause of extinction of some species in the collection. Hybrids inherit susceptibilities from the parents, e.g., to SLV from onion and to LYSV from *A. albidum* and *A. obliquum*, respectively (Senula et al. 2000). The test antibodies for this study were kindly provided by BBA Braunschweig.

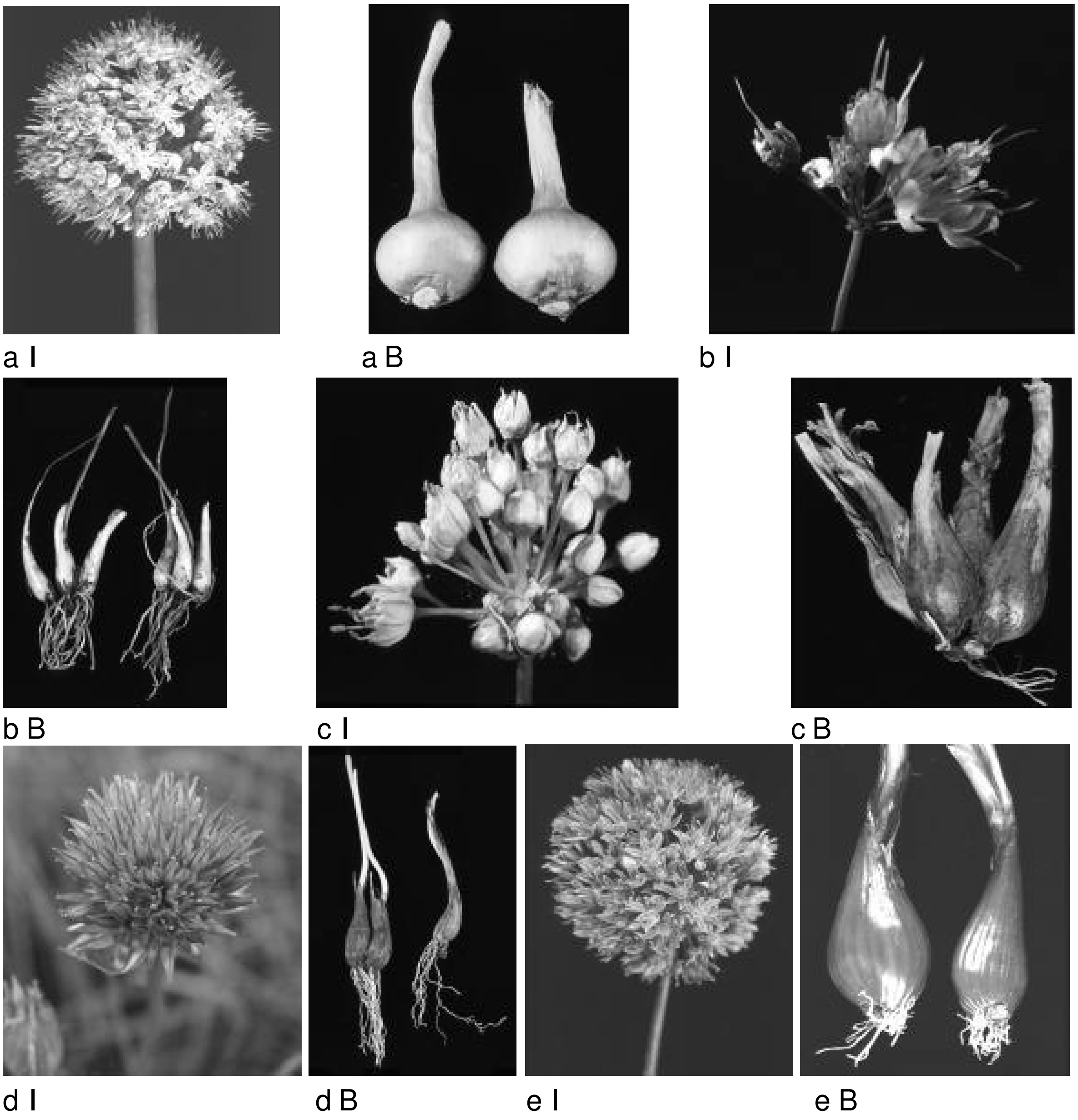
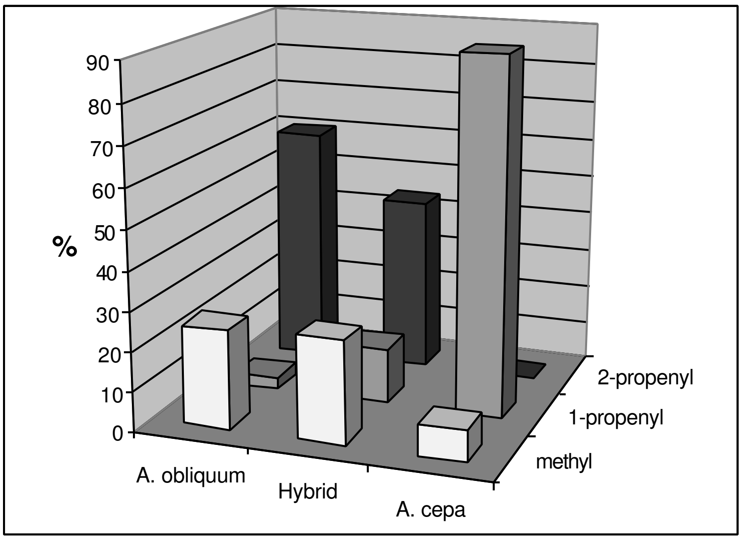


Fig. 1: Inflorescences (I) and bulbs (B) of some *Allium* species and hybrids
a: *Allium cepa*; b: *A. chevsuricum*; c: *A. cepa* × *A. chevsuricum*; d: *A. karelinii*; e: *A. cepa* × *A. karelinii*

Fig. 2:
Relative percentages of some selected cysteine sulfoxides in the basal parts of the plants
Note that the hybrid plants show intermediate behaviour

Discussion and conclusions



The genepool of wild *Allium* species accumulated in the Gatersleben collection provides a good background for hybridisation programmes in breeding and basic research. Examples demonstrated in this study are an initial step for further strategies. Primary hybrids derived from distant crosses are usually seed-sterile. Therefore, diploidisation of the material should be attempted to obtain presumably fertile amphidiploid plants. One of the options to get such material is *in vitro* colchicination. First hybrids have been treated with colchicine in our laboratory. A sample of 150 plants from *in vitro* colchicine treatment has been transferred into the field. First measurements by flow cytometry resulted in 131 plants with doubled chromosome sets. Once the plants come to the flowering stage, seed set will be the final prove of successful production of fertile plants.

Management and sensible use of the genetic diversity within a group of crop plant species and their wild relatives offers a promising way to future use of the richness of their genepool.

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Tab. 1: Field infection of wild alliums and hybrids with *Allium cepa* indexed with ELISA and TPIA

Species	ELISA (MS)		TPIA (ST)	
A. cepa (female parent)	OYDV+SLV or LYSV+SLV		OYDV+SLV or SLV	
	Male Parent	Hybrid	Male Parent	Hybrid
A. albidum	LYSV or VF	LYSV+SLV or SLV	LYSV or VF	LYSV+SLV or VF
A. globosum	SLV	SLV	SLV or VF	SLV
A. hymenorrhizum	SLV or VF	SLV or VF	OYDV or VF	SLV or VF
A. lineare	LYSV or VF	SLV or VF	LYSV or VF	SLV or VF
A. obliquum	LYSV	LYSV+SLV	LYSV+SLV	LYSV+SLV
A. rubens	VF	SLV	VF	SLV
A. saxatile	VF	SLV	VF	SLV
A. senescens	VF	VF	VF	VF

Abbreviations: ELISA – enzyme-linked immunosorbent assay, LYSV – leek yellow stripe virus, MS – mixed samples, OYDV – onion yellow dwarf virus, SLV – shallot latent virus, ST – single leaf test, TPIA – tissue print immunoassay, VF – virus free. The underlined viruses cause more or less serious disease symptoms.

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Molecular mapping and geographical distribution of genes determining anthocyanin pigmentation of coleoptiles in wheat (*Triticum aestivum* L.) [1]

E.K. KHLESTKINA [2], E.G. PESTSOVA [2, 3], M.S. RÖDER [3] and A. BÖRNER [3]

Anthocyanin pigmentation of different parts of the plants is found in many species including the cereals. In wheat major genes are known for the coloration of coleoptiles, auricles, straw, anthers or grains (MCINTOSH et al. 1998). For coleoptile colour three major genes were described (MCINTOSH et al. 1998) to be located on chromosomes 7A (*Rc1*), 7B (*Rc2*) and 7D (*Rc3*), respectively. The present study was initiated in order to map the three homoeologous group 7 red coleoptile colour genes in wheat by using microsatellite markers. In addition we investigated the geographical distribution of those genes in 468 mainly European wheat varieties.

Materials and methods

Two intrachromosomal substitution lines 'Chinese Spring/Hope 7A' (*Rc1*) and 'Chinese Spring/Hope 7B' (*Rc2*) were crossed with the non-coloured spring wheat genebank accessions TRI 15010 and TRI 2732, respectively, originating from Ethiopia and China (Tibet), respectively. For mapping *Rc3* on chromosome 7D a mapping population of the cross 'Mironovskaya 808' × 'Aibian 1' was used. In addition the parents and 109 recombinant inbred lines of the 'International Triticeae Mapping Initiative' (ITMI) population were evaluated phenotypically. The seeds were placed on moistened filter paper and coleoptile colour was scored after five to seven days. Fresh leaves were used for DNA extraction. Wheat microsatellite markers known to map on chromosomes 7A (31), 7B (34) and 7D (26) were selected and used as described by RÖDER et al. (1998). The phenotypic data obtained from the ITMI population were integrated into a framework map (RÖDER et al. 1998). Linkage maps were constructed with the MAPMAKER 2.0

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computer program (LANDER et al. 1987); QTL-analysis was performed using the QGENE application (NELSON 1997).

Genetic mapping

The phenotypic segregation data, obtained from scoring F_2 or F_3 populations gave clear indication for a monogenic inheritance of the target trait as proven by χ^2-test. From the wheat microsatellites tested, 20 out of 31 (chromosome 7A; 65%), 23 out of 34 (chromosome 7B; 68%) and 11 out of 26 (chromosome 7D; 42%) were found to be polymorphic between the parents. The three coleoptile colour genes were mapped about 15 to 20 cM distal from the centromere on the short arms of the homoeologous group 7 chromosomes. Since the map positions of all three genes are highly comparable it may be concluded that they are members of a homoeologous series. According to the rules for the symbolisation of genes in homoeologous sets, we propose to designate the group 7 red coleoptile colour genes as *Rc-A1*, *Rc-B1* and *Rc-D1*, respectively. Further homoeologous loci may exist on chromosome 7R in *Secale cereale* (*an1*) and on chromosome 7H in *Hordeum vulgare* (*ant1*). When analysing the ITMI population, two QTLs were mapped within intervals, highly comparable to the regions where the major genes in the F_2/F_3 mapping studies were detected. It could be suggested that the A genome of *Triticum durum* and the D genome of *Aegilops tauschii* are carrying homoeologous loci determining red coleoptile colour.

Geographical distribution

Most of the 468 varieties tested, about 60% (273), were found having non coloured coleoptiles, whereas in 23% (107) and 6% (26) of the wheat genotypes red and dark red coloured coleoptiles, respectively, were detected. Sixty-two varieties (13%) were segregating. The highest percentage of varieties with red coloured coleoptiles was found in material from the United Kingdom (62%), followed by France (38%) and Germany (28%). High frequencies of segregating varieties were discovered in material from the Ukraine (25%) and France (23%). Interestingly, the frequency of varieties having red coloured coleoptiles was lower in Southern and Eastern Europe compared to Western European countries. A list with the results for all tested varieties is presented by KHLESTKINA et al. (2001).

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English translation of the 1979 Russian taxonomic monograph of *Triticum* L. by Dorofeev *et al.*: Project progress report

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Abstract

DOROFEEV et al. (1979), the taxonomic monograph of *Triticum* L. published by the N.I. VAVILOV Institute of Plant Industry (VIR) is an important work which is largely unknown outside of Russia due to the language barrier. A morphological treatment, this monograph is at odds with current genetic concepts of wheat taxonomy and is therefore controversial. It is the only complete modern catalogue of wild and domesticated forms of *Triticum* species. For germplasm diversity and intellectual property rights, DOROFEEV et al. can prove its value as an authoritative source that can be consulted for issues relating to the validity of proprietary claims on wheat genes and genetic lines that rightfully belong within the public domain. In 1999, an international collaboration was formed to support the translation of DOROFEEV et al. into English (MORRISON et al. 2000). A project fund that was started by a US$ 5,000 donation from CIMMYT has been established at the "Society for the Advancement of Cultivated Plant Research in Gatersleben" (GFK). The project is currently seeking additional matching funds. The translation of the text has been completed by I. SOKOLOVA, a botanist from the Komarov Botanical Institute, St.

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Petersburg, Russia. A. FILATENKO, one of the original authors, is currently reviewing the translated copy, and adding necessary details and corrections. English editing is underway during 2002 by CH. JEFFREY, St. Petersburg. Publication of an affordable translation is projected for 2003/2004. Internet copies of the taxonomic keys and descriptions are also planned. The full text of the poster, which also includes an example of the translated text for *Triticum urartu* Thum. ex Gandil., was published elsewhere (KNÜPFFER et al. 2002).

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Development and evaluation of a *Brassica napus* core collection

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Abstract

To optimise the exploitation of genetic resources in plant breeding, the EU-funded project RESGEN CT99 109-112 has been initiated. This joint project aims at conserving, documenting, characterising, evaluating and rationalising European collections of the crop species *Brassica napus* L., which encompasses oilseed rape and some fodder crops (ssp. *napus*) along with rutabaga or Swede turnips (ssp. *napobrassica* (L.) Hanelt). In a first step, a preliminary *B. napus* core collection representing a broad variation selected from the available accessions in the European central database (*Bras-EDB*) has been created. Besides morphological and quality assessment of the material, the main task will be the evaluation of the core collection regarding resistance to clubroot disease (*Plasmodiophora brassicae*) and pests, such

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as flea beetles (*Psylliodes chrysocephela, Phyllotreta* spp.), stem weevils (*Ceutorhynchus* spp.) and field slugs (*Deroceras* spp.).

Introduction

Brassica crop species have become one of the most important sources of oil, condiments, vegetables, forage and green manure world-wide (cf. DIEDERICHSEN 2001).

The co-operative project "*Brassica* collections for broadening agricultural use, including characterising and utilising genetic variation in *Brassica carinata* for its exploitation as an oilseed crop" (RESGEN CT99 109-112) has been initiated in order to increase knowledge about the genetic resources available within the four important *Brassica* species *B. oleracea*, *B. rapa*, *B. napus* and *B. carinata*, and to improve the utilisation of their genepools in Europe by plant breeders and growers. To achieve this, core collections are being established for each of the four species, with the intention of providing coverage of the maximum possible variation available within existing material in a representative set of well-characterised genotypes. In addition to seed regeneration and characterisation of the material, extensive evaluation of the four core sets with respect to important agronomic and phytopathological traits is being carried out, with results to be made freely available via the European database *Bras-EDB* (cf. BOUKEMA and VAN HINTUM 1999, LÜHS et al. 2002).

Gross evaluation of *B. napus* accessions

With the objective of creating such a *B. napus* core collection from all accessions documented in *Bras-EDB*, a maximum quantity of information about the growth habit, use and seed quality of the material integrated in the database has to be collected.

Differentiation between spring and winter *B. napus* types*:* For a basic differentiation of the *B. napus* accessions (excluding ssp. *rapifera*), the characters winter hardiness, vernalisation requirement, seasonality and type of use were used (Tab. 1). Following this gross grouping of the material, 338 summer type *B. napus* accessions - including oilseed rape varieties, fodder and green manure forms as well as „exotic" types, incl. vegetables (ssp. *pabularia*), Hakuran, Couve Nabica - were grown at the Field Research Station in Rauischholzhausen (near Marburg/Hesse, Germany) in 2000. In the vegetation period 2000/2001, a total of 857 *B. napus* winter type accessions were sown for the same reason. In this trial genotypes were included that in the preceding spring trial displayed a biannual growth habit (vernalisation requirement) and stayed vegetative like forage types. Due to a relatively mild winter period in 2000/2001, nearly all of these accessions survived and showed transition to the generative stage. In addition to basic description of this large set of *B. napus* material (excluding ssp. *rapifera*), the growth and generative characters were evaluated, viz. beginning and end of flowering and harvest time. The Swede or rutabaga material to be included in the core collection was evaluated earlier as a separate set at the Nordic Gene Bank (Alnarp, Sweden).

Tab. 1: Differentiation of *B. napus* forms due to vernalisation requirement and seasonality (excluding Swede or rutabaga types)

Winter hardiness	Type	Seasonal type	Use	Descriptor
	perennial			5
Present	*biennis*	winter biannual	oil	4
	biennis	winter annual	forage	3
Not present	*biennis*	summer annual	forage	2
	annua	summer annual	oil/forage	1

Seed quality analyses: In breeding of *Brassica* crops, the percentage of erucic acid content in the seed oil and the glucosinolate content of the meal are very important quality characteristics. The genebank accessions could be classified as follows:

1) high erucic acid-high glucosinolate (HEAR),
2) low erucic acid-high glucosinolate (LEAR),
3) high erucic acid-low glucosinolate, and
4) low erucic acid-low glucosinolate (double low quality, canola).

For seed quality analyses in each plot three to five plants were isolated with bags to obtain seeds for fatty acid analysis, while the open-pollinated seed material was collected for oil, protein and glucosinolate analysis by near-infrared reflectance spectroscopy (NIRS).

The erucic acid content, which was determined in selfed seed material from individual plants of accessions included in the spring trial, showed considerable variation (Fig. 1). Following the differentiation of the material in HEAR and LEAR/canola types in both major quality groups, off-types - low-erucic types in the HEAR group and high erucic individuals in the LEAR/canola group, respectively - were observed. A similar variation was found for the low-glucosinolate spring rape cultivar ‘Bronowski’, which is known to have an erucic acid content of 8-10% and displayed a range of 0-35% (cf. Krzymanski and Downey 1969, Anand and Downey 1981). The seed analyses clearly demonstrate that the seed material obtained from different European gene-

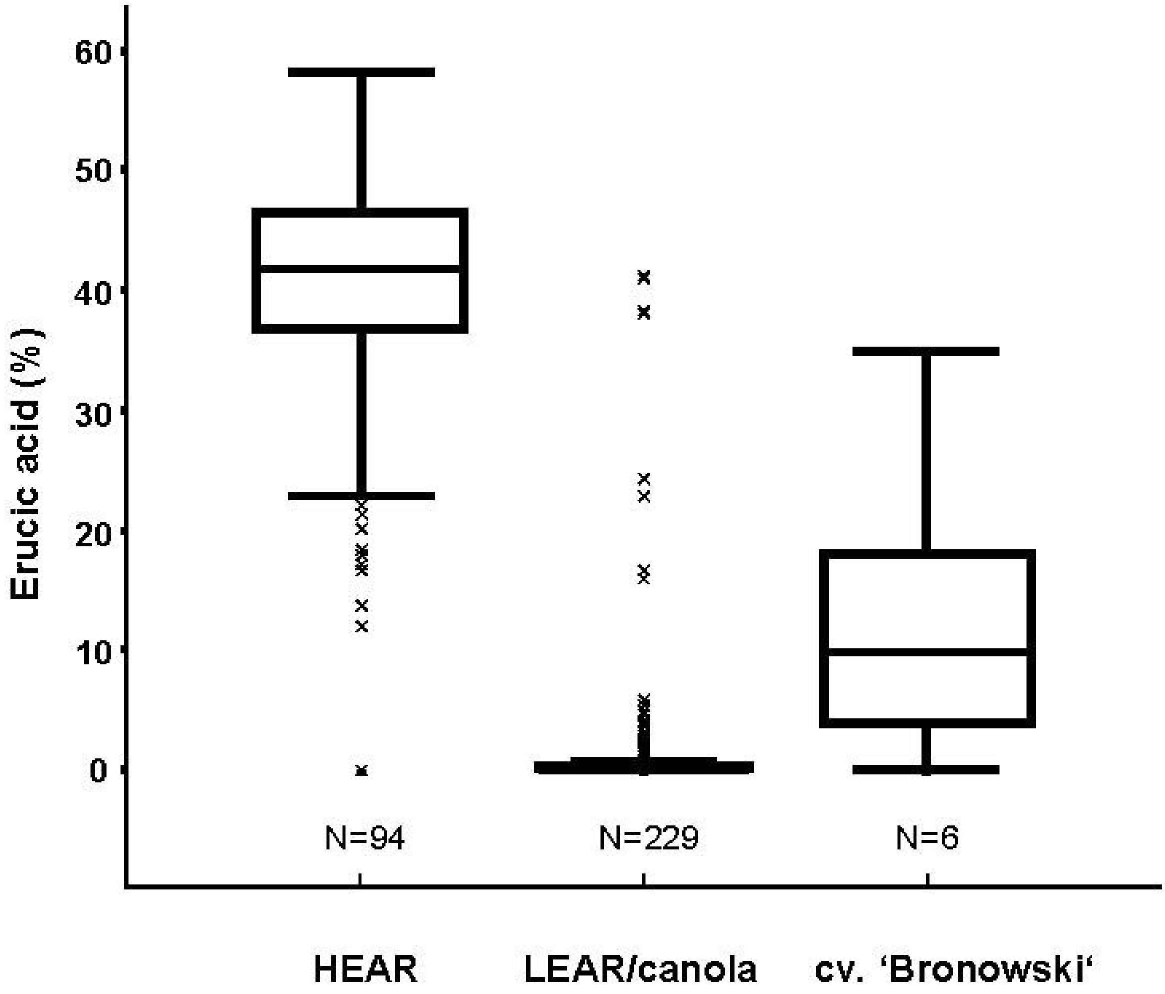

Fig. 1: Variation of erucic acid content in selfed seed material from individual plants of *B. napus* accessions, grouped according to their seed oil quality in HEAR and LEAR/canola types as well as different accessions of cultivar 'Bronowski'
(N = number of individual plants; spring trial, Rauischholzhausen, 2000)

banks may have been contaminated during seed regeneration due to cross pollination.

Evaluation with respect to phytopathological traits

Depending on the biology of the respective pests, winter oilseed rape is attacked twofold: In the seedling stage by cabbage stem flea beetle (*Psylliodes chrysocephela*) and in early spring by larvae of stem weevils (*Ceutorhynchus napi*, *C. quadridens*) mining the stems of the plants. *Phyllotreta* flea beetles on the other hand, are insect pests of exclusively spring varieties. In the present study the rapeseed plants, sown in randomised field plots, will be screened for damage caused by larvae of *Ceutorhynchus* spp. and/or adult flea beetles (cf. WINFIELD 1961, LAMB 1989, PENG et al. 1992, GIAMOUSTARIS and MITHEN 1995). As breeding of double-low cultivars of oilseed rape has successfully reduced the seed glucosinolate content, some secondary plant compounds have gained importance with regard to certain pests. In the green matter glucosinolates are beneficial due to their function as feeding deterrents or toxins for polyphagous herbivores, such as field slugs. On the other hand, glucosinolates or their fission products are involved as attractants in interactions with specialised insects feeding and/or reproducing on cruciferous crops (CHEW 1988, GLEN et al. 1990, GIAMOUSTARIS and MITHEN 1995). Therefore, it will be of interest to analyse the material for glucosinolate composition when considerable variation exists regarding the response against the above-mentioned pests.

Outlook

The extensive phenotypic and quality data is being used to select accessions representing the variability within the species *B. napus* and to establish a reliable European core collection of 150-200 accessions including Swede turnip or rutabaga types (ssp. *napobrassica*). In a second step, the *B. napus* subgroup of the RESGEN project aims at evaluating the core collection regarding resistance to clubroot disease (*Plasmodiophora brassicae*) and important pests including flea beetles (*Psylliodes chrysocephela, Phyllotreta* spp.), stem weevils (*Ceutorhynchus* spp.) and field slugs (*Deroceras* spp.).

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Maca (*Lepidium meyenii*) - cultivation, resistance and composition of secondary metabolites under European conditions

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Introduction

From the New World, a large amount of new crop plants came to Europe and afterwards to Asia and Africa. Many of them are of great importance world-wide such as maize, potato, tomato and others. Maca (*Lepidium meyenii* Walp.) was domesticated about 2,000 years ago in Mesoamerica. Nowadays the growing area of this crop is only about 50 ha in its originating region, the Departments of Junin and Cerro de Pasco, Peru (SPECHT 2001). But this neglected crop has some exceptional features such as growing at an altitude of up to 4,450 m in the Andean mountains, a starchy root-hypocotyl bulb and its extensive use in traditional folk medicine (aphrodisiac, enhancing female fertility in humans and animals) (QUIROS et al. 1996, QUIRÓS and CÁRDENAS 1997). The fresh hypocotyl bulb contains more than 80% water. The composition of main compounds in the dry matter comprises carbohydrates (59%), lipids (2.2%, good composition of unsaturated compounds), proteins (10.2%, high content of essential amino acids) and a fibre content of 8.5% (DINI et al. 1994). The bulb can be eaten fresh or dried as powder together with milk and fruits.

This paper presents, for the first time, information about secondary metabolites, resistance to important phytopathogens and cultivation under European conditions.

Material and methods

Two accessions (203 and 204) of maca were used for the analyses and tests.

Glucosinolates and flavonoids were determined by HPLC-method. Glucosinolate, HPLC-conditions: system: System 1100 (Hewlett Packard with DAD), column: ZORBAX XDB C18 150 x 2.1 mm; 3.5µ, flow: 0.55 ml/min, gradient: A (H_2O) / B

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(CH_3CN) (99:1; start conditions), 17.5 min: B 25%, 20.0 min: B 25%, 25.0 min: B 1%, analytic time: 30 min, column temperature: 35°C, wave length: 229 nm, internal standard: sinigrine; determination as desulfoglucosinolates. Flavonoids, HPLC-Conditions: system: System 1100 (Hewlett Packard with DAD), column: ZORBAX SB C18 150 x 2.1 mm; 3.5µ, flow: 0.50 ml/min, gradient: A (1% COOH)/ B (CH_3CN) (100:0; start conditions), 4.0 min: B 0%, 25.0 min: B 25%, 30.0 min: B 60%, 30.1 min: B 60% flow: 0.70 ml/min, 35.0 min: B 0% flow: 0.70 ml/min, 40.0 min: B 0% flow: 0.50 ml/min, analytic time: 40 min, column temperature: 35°C, wave length: 288 nm. To isolate the volatiles, an isooctane extract was prepared.

Resistances were tested by inoculations of plants with a suspension separately for each pathogen: *Alternaria brassicae*, *A. brassicicola, Phoma lingam* and *Plasmodiophora brassicae*. All tests were carried out in climate chambers under defined conditions (18-23 °C, 16 h light, humid conditions 7 days past inoculation). The turnip mosaic virus (TuMV) was tested by mechanical inoculation under green house conditions. Plants were rated for disease reaction 4 weeks after inoculation by ELISA immunotest.

Results and discussion

Both accessions were grown from April to November in the experimental field. The plant development was very slow – at the end of vegetation period the hypocotyl bulbs reached 1 to 1.5 cm. No plant survived the winter outside. Plants which were grown in the greenhouse needed a vernalisation period of about 12 weeks (0 - 4 °C, 12 h light). The flowers are self-fertile.

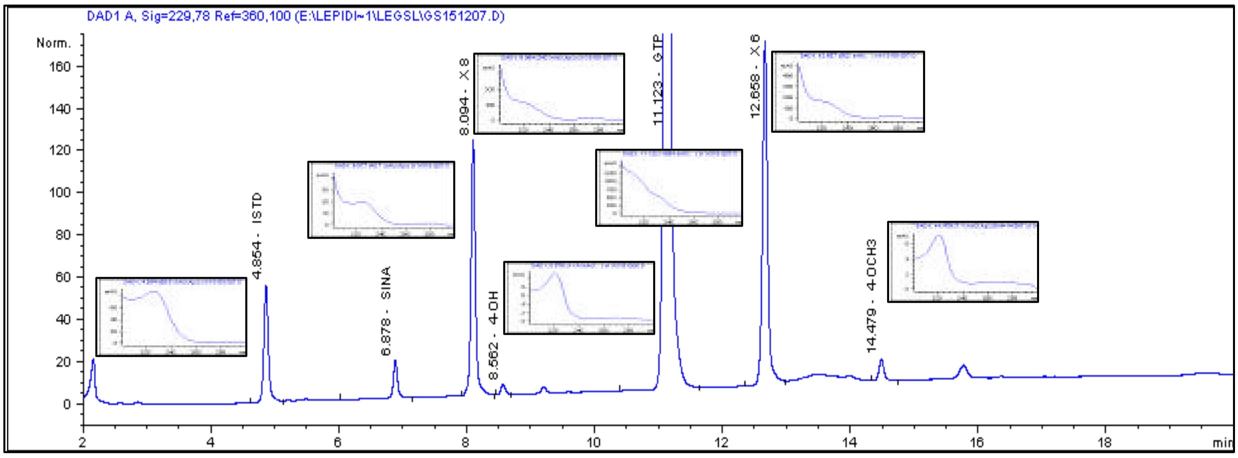

Fig. 1: HPLC-separation of glucosinolates from a root extract of maca and UV-spectra

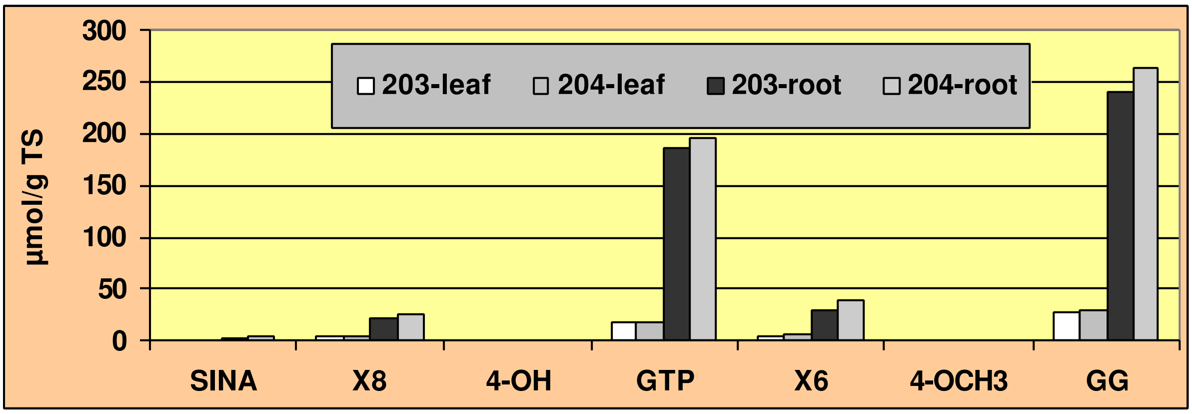

Fig. 2: Glucosinolate content and distribution patterns in leaves and roots of two different origins of maca
SINA - sinalbine, X8 - benzylglucosinolate, 4-OH - 4-hydroxy-glucobrassicine, GTP - glucotropaeoline, X6 - benzylglucosinolate, 4-OCH3 - 4-ethoxy-glucobrassicine, X6 and X8 are not yet identified, GG - glucosinolates in total

Composition and amount of secondary metabolites were intensively analysed. In leaves and roots, maca contains large quantities of glucosinolates (Figure 1). Glucotropaeoline is the main glucosinolate with quantities of around 20 µmol/g ds in leaves and up to 195 µmol/g ds in roots. In addition, other glucosinolates were found in smaller amounts: sinalbine, X8-benzylglucosinolate, 4-hydroxy-glucobrassicine, X6-benzylglucosinolate and 4-methoxy-glucobrassicine. Glucosinolates X6 and X8 have not been identified so far. Both origins differ likewise quantitatively, but not qualitatively (Figure 2).

In maca also small quantities of flavonoids were determined. Up to now both substances were not identified (Figure 3). No volatile substances could be found.

Resistance to phytopathogens important in crops of the genus *Brassica* was tested: *Alternaria* blight, black leg and leaf spots, clubroot and virus disease caused by *Alternaria brassicae* and *A. brassicicola, Phoma lingam, Plasmodiophora brassicae* and turnip mosaic virus (TuMV), respectively. The tested accessions were susceptible to all these pathogens.

Maca flavour was tested organoleptically. It has a pungent smell and sharp stinging sensations after chewing.

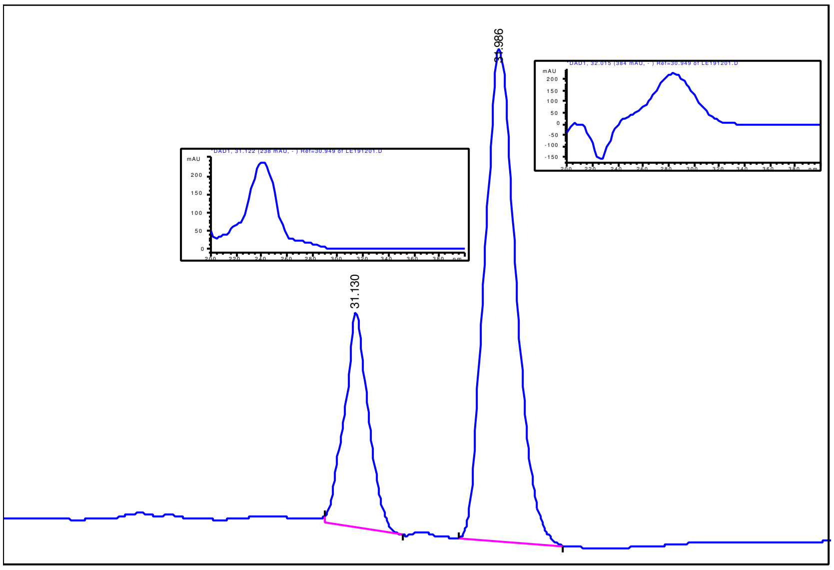

Fig. 3: **HPLC-chromatogram section from a root extract of maca with UV-spectra, both flavonoids are not identified**

Acknowledgement

The authors thank Prof. C.F. Quirós, University of California at Davis, USA, for providing the maca seeds.

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Mansfeld's Encyclopedia and Database of Agricultural and Horticultural Plant Species

J. OCHSMANN [1,2], H. KNÜPFFER [3], N. BIERMANN [3] and K. BACHMANN [1]

In 1959 Rudolf Mansfeld published his "Preliminary Catalogue" of cultivated crops (MANSFELD 1959). Whereas this work was mainly compiled by himself, the second edition (SCHULTZE-MOTEL 1986) was already compiled by a team of authors. The first English edition, "Mansfeld's Encyclopedia of Agricultural and Horticultural Crops" (HANELT and IPK 2001), was prepared by a team of 20 authors (PISTRICK 2002). An online database (http://www.mansfeld.ipk-gatersleben.de/) has been established on the basis of this recent edition of the book, already with a number of additions. The scope of the book and the database are agricultural and horticultural cultivated plants world-wide, including algae, fungi, pteridophytes and gymnosperms, excluding ornamental and forest plants. The different types of information included for over 6,100 species are (1) accepted name, (2) synonyms, (3) taxonomic remarks, (4) common names in various languages, (5) distribution (wild and cultivated), (6) plant uses, (7) wild relatives, (8) cultivation and domestication history, (9) bibliographical references, and (10) images. A survey showing the number of records is presented in Table 1.

Tab. 1: Database statistics

	total	accepted
Scientific names	36,718	9,796
Species	25,721	6,117
Genera	6,258	1,968
Families	277	265
Common names	30,165	
Languages	116	
References	7,622	
Images	335	

In the future, the Mansfeld database will form the taxonomic core of a broader information system on cultivated plants with links to other databases (Table 2).

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Tab. 2: Databases to be connected with the Mansfeld Database

local IPK databases	external sources
passport data of germplasm accessions	common names
agronomic evaluation data	country-specific databases on cultivated plants
taxonomic monographs	molecular data
country checklists	images
IPGRI Home Garden Database	

Other local databases from the Institute for Plant Genetics and Crop Plant Research Gatersleben (IPK) will be integrated into the database system in form of modules (Figure 1), external sources will be connected by dynamic links. The modular structure of the planned information system will allow integrating further types of data with a minimum of adaptation of the system.

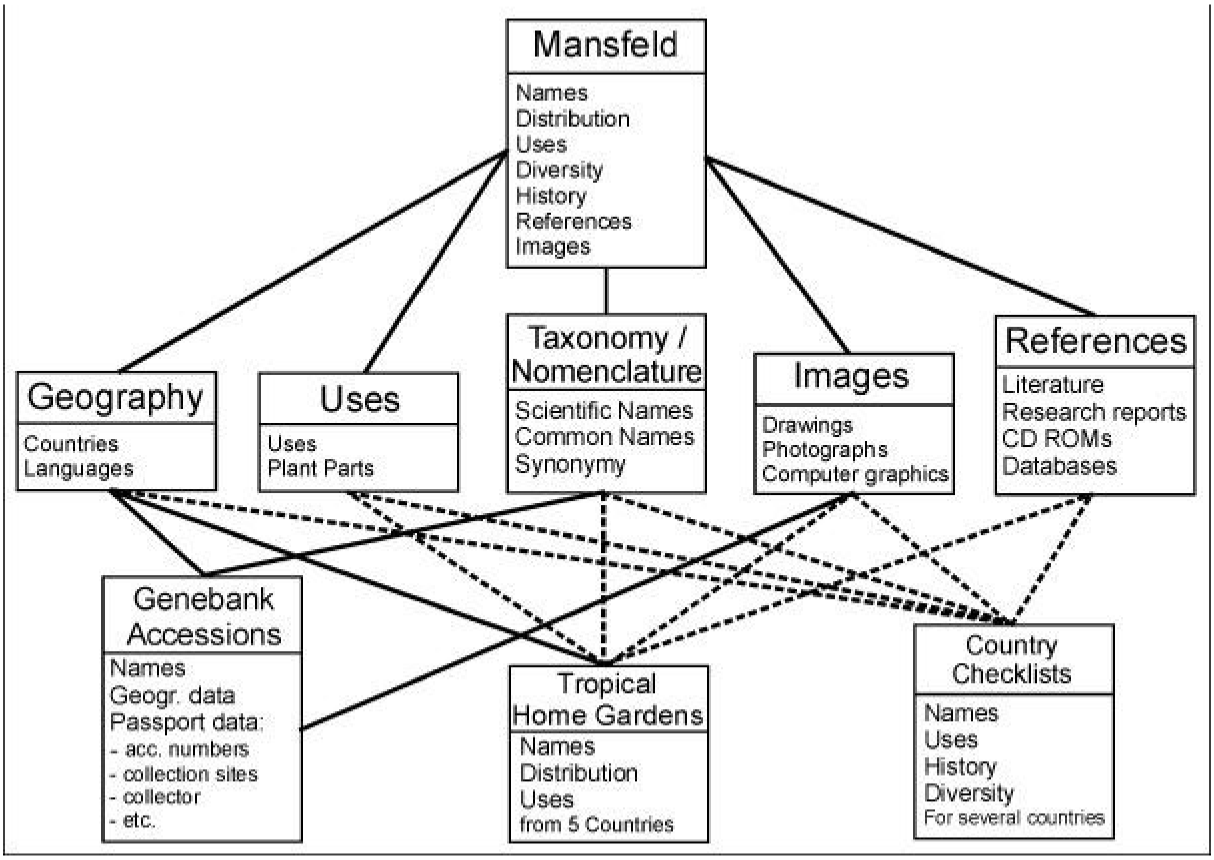

Fig. 1: Structure of the Mansfeld Database and the intended information system
(black lines indicate existing relations, dotted lines indicate the future structure)

Additionally, by grouping the information in modules, duplications can be avoided and the editing of the data can be optimised. For the same reason, international standards will be followed as far as possible, e.g. for authors abbreviations (BRUMMITT and POWELL 1992, IPNI), geographical data (BRUMMITT 2001), and plant uses (COOK 1995). Tools will be developed for online-editing that should provide convenient means for updating the information.

The database development is part of the project "Federal Information System on Genetic Resources" (BIG) (http://www.big-flora.de/), which involves four German partner institutions, and is co-ordinated by the German Centre for Documentation and Information in Agriculture (ZADI): (1) Central Agency for Agricultural Documentation and Information (ZADI), (2) Ruhr University Bochum (RUB), (3) Federal Agency for Nature Protection (BfN), and (4) Institute of Plant Genetics and Crop Plant Research (IPK) (ROSCHER et al. 2002). The project is funded by the German Ministry of Research and Technology (BMBF) and includes, in addition to the Mansfeld database, information on plant genetic resources available in German genebanks and botanical gardens floristic mapping of the German flora, and other PGR-related data sets. Through a common search interface it is possible to search these heterogeneous databases simultaneously.

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The information system on plant genetic resources of the N.I. Vavilov All-Russian Institute of Plant Industry (VIR)

A. OMELCHENKO [1], S. ALEXANIAN [1], S. HARRER [2] and A. SERBIN [2]

Within the USSR, the N.I. Vavilov Research Institute of Plant Industry (VIR) was the only organisation working on the whole complex of problems related to genetic resources of cultivated plants and their wild relatives. VIR had been actively involved in explorations and germplasm collecting throughout the world, maintaining the collected germplasm in its genebank and provided it to various users, carrying out characterisation and preliminary evaluation of the accumulated genetic stocks, developing documentation, and training specialists. VIR possessed a vast network of 19 experiment stations which maintained working collections, carried out research and reproduction of accessions. After the break up of the USSR, six experiment stations, namely those in Ukraine, Kazakhstan, Turkmenistan, Georgia and Uzbekistan appeared to be the major holders of national germplasm collections in these countries.

VIR's global PGR collection represents plant diversity encompassing 320,000 accessions of 155 botanical families, 2,532 species of 425 genera. For instance, the collection harbours 95,000 accessions of grain crops, over 43,000 of legumes, 52,000 of "groat crops" (e.g. rice, sorghum, millets and pseudocereals), 26,000 of industrial crops, 28,000 of fodder crops, about 10,000 of potato, and 50,000 of vegetables. About 200,000 accessions were placed for long-term storage in the genebank built in 1976. VIR also maintains a herbarium of 260,000 specimens. The network of VIR includes the institute's headquarters with nine plant resources departments, 13 fundamental research laboratories, and 12 experiment stations in different geographic zones of Russia.

The institute's collections, pre-bred materials and other sources identified and developed by VIR's scientists have played a decisive role in breeding. Utilisation of germplasm materials from VIR by breeders in Russia alone has resulted in the release of over 2,500 cultivars, of which 450 are now cultivated on an area of 63 million hectares. This is valid for 80% of wheat cultivars. The annual mean

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percentage of released cultivars bred on the basis of VIR collections is 45% of all cultivars released nation-wide, with 77.7% of all potato cultivars, 66.1% of new cultivars of grain crops, 54.7% of legumes, and 50% of vegetables.

Primary evaluation helped to identify about 4,000 sources of valuable breeding characters. Genetic investigations localised 77 sources including 27 sources of resistance to the pathogens of wheat, barley, oats, peas, etc., and 9 sources of earliness in oats, maize and sunflower.

The collection is not only used for national benefit, but also in the best interests of the international community.

VIR collaborates with the ex-USSR republics and continues to supply plant materials at requests from breeders. From 1996 through 2000, these countries received over 14,000 samples of various crops. In recent years, pursuant to the CBD, many countries have displayed interest in repatriation of their own PGR.

VIR has established efficient cooperation with more than 40 countries of the world, e.g. joint projects with the Centre for Genetic Resources, The Netherlands (CGN), the German Centre for Documentation and Information in Agriculture (ZADI, Germany), and the Nordic Gene Bank (NGB, Sweden).

Since its establishment in 1894, VIR has accumulated impressive quantities of data associated with plant germplasm held in its genebank. The largest part of these data have been recorded on cards and in paper reports. During the last years, this information became gradually computerised. But there was still a limited availability of data for people outside the institute.

The next stage, which has already started, will be modification of the Vavilov Global Collection Information and Documentation System to give users better opportunity to access and use data on the largest and most important crop collections.

As a result of a joint project between the VIR and the Information Centre Genetic Resources (IGR, now: Information Centre for Biological Diversity, IBV) at ZADI in Bonn, the VIR Information System (http://www.genres.de/vir/) has been developed, to provide this valuable information for everybody via internet.

Following the most recent update, the system now provides information on the structure and history of the Institute, examples of VIR's scientific work, the list of WWW Libraries and Biological Journals, and one can find Internet addresses for some Russian scientific organisations in agriculture. For each department and experimental station there is a short description available, including names and contact details of responsible scientists. A question and answer service also assists in making it more straightforward to contact VIR staff.

The most important part of the VIR Information System is the online database. The aim of this information service is to improve access to and use of the collections held at VIR through the increased availability of the related data. To date, 250,000 accessions of passport catalogue, have been verified and access to the passport data of approximately 90% of this collection is now possible through direct searches on the Internet.

Access to the database is possible either by using a crop list or by using a search form for all thirteen fields of the database. Decoding tables are also available by downloading compressed files. Over the last year, the site has had an average of about 2,500 hits per month.

Since 2000, the website of the VIR is also available via http://www.vir.nw.ru.

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Characterisation of spring barley genetic resources in Yugoslavia

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D. KOPAHNKE [3], F. ORDON [4] and A. GRANER [5]

Abstract

A collection of 106 spring barley landraces from Yugoslavia was evaluated and assessed for some morphological and agronomical characters and tested for resistance to Barley Mild Mosaic Virus (BaMMV) and leaf rust (*Puccinia hordei*). In the collection, two genotypes (MB530 and MB532) showed resistance to BaMMV. After artificial inoculation with leaf rust, one genotype (MB1012) turned out to be resistant. Based on mainly quantitatively inherited characters, a cluster analysis was carried out and a dendrogram was constructed. The level of diversity detected and the potential use of this germplasm in breeding programmes are discussed.

Introduction

Cultivated barley (*Hordeum vulgare* L. ssp. *vulgare*) ranks fourth in world cereal production, and is the third most important agricultural species in Yugoslavia (MAKSIMOVIC et al. 1996). Because of the long cropping tradition and its present economic importance, there was an initiative from 1960-1980 to collect and store barley genetic resources from different locations across Yugoslavia. Collection sites were within a range of environmental conditions [altitude (-5 to +1,600 m a.s.l.), precipitation (250

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to 4,000 mm/m$^{2)}$, soil type (chernozem, sandy...), exposition, etc]. At present, the Yugoslavian barley gene bank holds about 150 barley accessions representing putative landraces and about 80 cultivars from three breeding institutes. To promote their effective use in plant breeding programmes, genetic resources need to be characterised and evaluated for different taxonomical, morphological, physiological and agronomical traits. This study presents first results on the characterisation and the evaluation of 106 barley landraces from Yugoslavia.

Material and methods

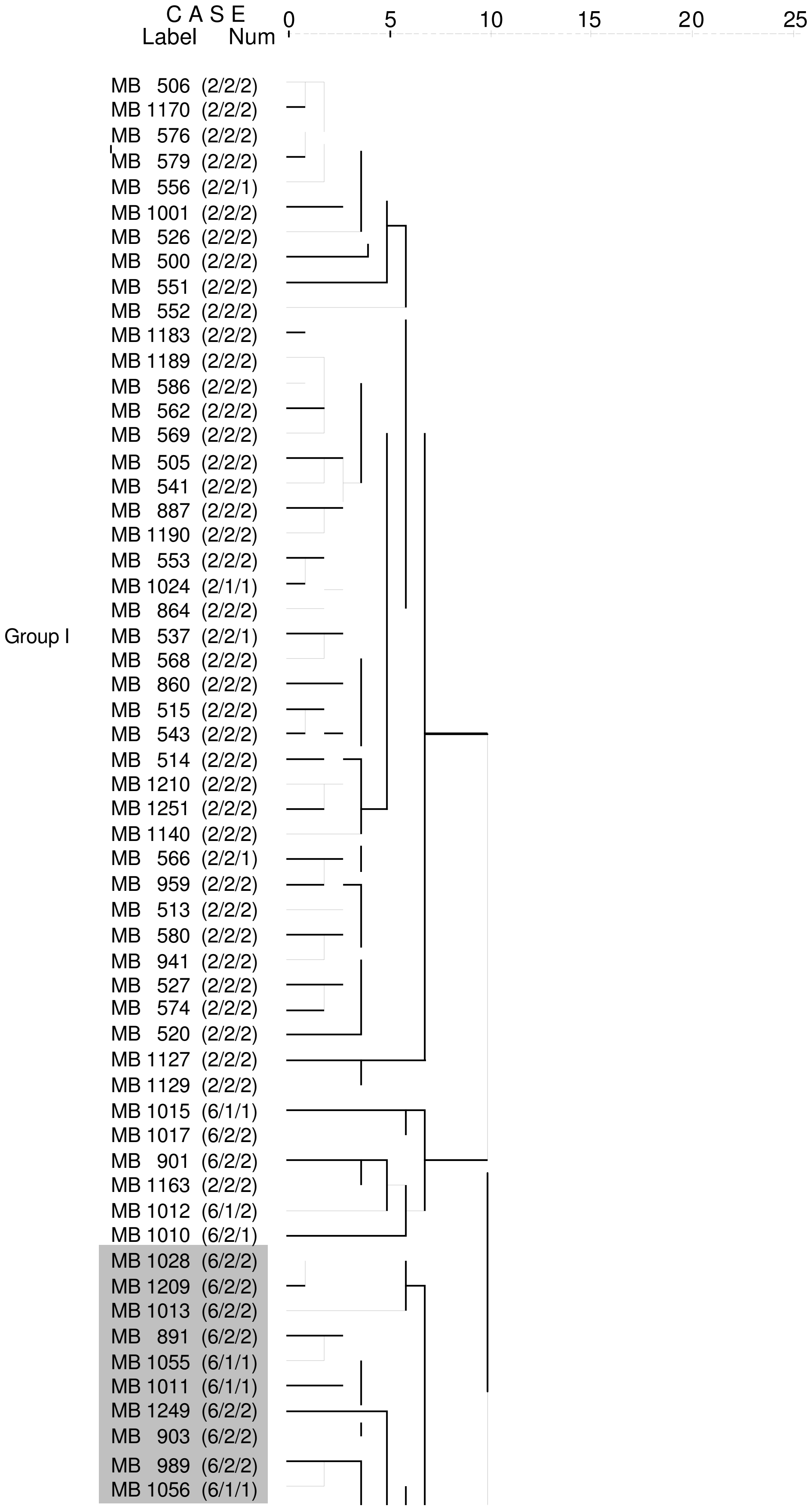
Selected landraces were grown at two locations in Yugoslavia (Novi Sad and Kragujevac) and Gatersleben (Germany). They were sown manually in rows of 2 m length, with 5 cm spacing between plants, and harvested manually at the full maturity stage. Measurements were performed on ten individual plants of each accession. Only data obtained from field experiments at Kragujevac were used for the assessment of genetic variability and diversity within this collection. Values of 16 quantitative traits (Table 1) were taken for cluster analysis. Qualitative traits (number of rows in spike, spike form and presence of awn dent) were not taken into account for this computing. Hierarchical clustering was done by the method of linkage between the groups, based on the square Euclidean distances. All calculations and the construction of vertical dendrograms were performed using SPSS W 10.0.

In addition, resistance tests for Barley Mild Mosaic Virus (BaMMV), and leaf rust (*Puccinia hordei* Otth.) were performed. Five plants per genotype were mechanically inoculated in two replications with BaMMV and tested for resistance by DAS-ELISA. Regarding resistance to BaYMV-1 and BaYMV-2, field tests are in progress. Ten plants per genotype were artificially inoculated with the single spore isolate I 80 of leaf rust.

Results

The measured traits and their minimal, maximal and average values within the collected material are presented in Table 1.

Plant height varied from 56 to 94 cm, while the number of productive tillers was between 1 and 9. Variation in primary spike length was between 2.52 cm and 14 cm, with an average value of 7.94 cm. The difference in flowering time between the earliest and the latest accession amounted to 23 days. Some accessions were almost completely sterile. Variation in yield components, i.e., number and mass of grains per primary spike and grain mass of plant showed the greatest variation (sometimes the ratio minimal *vs*. maximal value is more than 10 times).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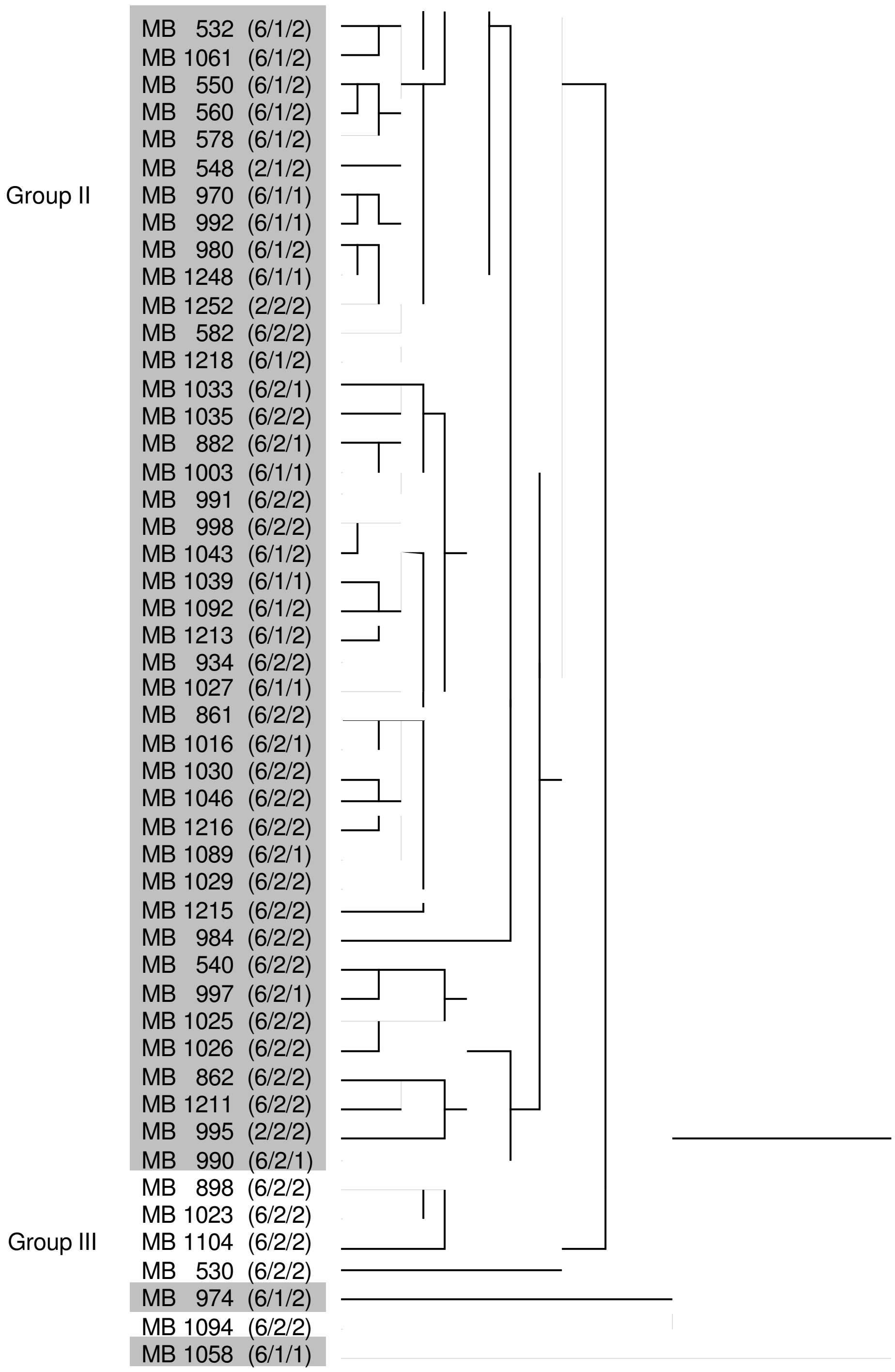

Fig. 1: Dendrogram of Yugoslavian barley landraces based on the values of 16 quantitative traits

Qualitative characters are presented in brackets for each genotype as follows: the first number (2 or 6) shows the number of rows in spike, the second number - absence (1) or presence (2) of awn-dent and the third one - pyramidal (1) or cylindrical (2) form of spike

Tab. 1: List of traits examined with a cardinal value for all accessions in the collection

Trait	Minimal value	Maximal value	Average
Plant height (cm)	56.00	94.00	76.96
Total tillering	1.67	16.00	7.30
Number of nodes	3.20	6.00	4.63
Productive tillers/plant	1.00	9.00	3.66
Sterile tillers/plant	0.60	8.83	3.66
Primary spike length (cm)	2.52	14.00	7.94
Plant weight (g)	2.01	18.93	8.38
Flag leaf length (cm)	4.25	20.55	11.68
Flag leaf width (cm)	0.45	1.76	0.91
Sowing/flowering period (days)	89.00	111.00	101.61
Fertile spikelets/spike	4.09	71.00	33.55
Sterile spikelets/spike	1.80	21.60	6.26
Grains/primary spike	7.00	86.00	28.85
Grain mass of primary spike (g)	0.35	2.58	1.23
Grain mass per plant (g)	0.48	8.37	3.32
Harvesting index	0.20	0.60	0.39

All the collected genotypes were awned. Out of 106 genotypes, two (MB530 and MB532) showed resistance to BaMMV. After artificial inoculation with a single spore isolate of leaf rust, only one resistant genotype (MB1012) was found. The dendrogram of the barley landraces in the collection is presented in Figure 1. They are clustered in three groups, of which the first two (I and II) are large (47 and 52 landraces, respectively), while the third one (III) is small and consists of only four landraces. Three barley genotypes are out-grouped from these main groups, each of them on the next higher level of clustering.

Discussion

In group I of the dendrogram (Fig. 1), most two-rowed landraces are included, while group II comprises almost all six-rowed landraces. This shows that one qualitative morphological character can strongly affect grouping, probably because of linkage to some of the traits scored. However, this is not the case with other analysed qualitative traits of barley. Therefore, genotypes with different awn-dent and spike form are randomly distributed in all clusters/subclusters. The presence of few six-rowed landraces (MB901, MB959, MB1010, MB1012, MB1015 and MB1017) in group I, as well as the presence of few two-rowed landraces (MB548, MB995 and MB1252) in group II suggests that some of the genotypes analysed differ significantly from all other genotypes of the same row-type. This could be useful in breeding for structural changing of spike architecture within or between both row-types. This phenomenon of deviation from original type is probably due to high diversity in the origin of the collected material in terms of different ecological conditions. For three landraces (MB974, MB1094 and MB1058), it was not possible to find any similar genotype in the collection and they are not grouped. Landrace MB974 has almost monoculm type of tillering, which was not found in any other genotype. It is specific for landrace MB1094 that spikelets are extremely separated (about 1 cm from each other). Plants of the landrace MB1058 are very high (94 cm) with many tillers (9 fertile) that form long spikes (14 cm) and that produce many grains (86 per spike) and high grain mass (26.45 g per plant). All observations mentioned suggest that diversity present in this Yugoslavian barley collection represents a good base for further selection of superior genotypes after inter-landrace crossing as well as for improving existing barley cultivars for some individual traits. Two accessions (MB530 and MB532) are resistant to BaMMV and one accession (MB1012) is resistant to *Puccinia hordei.* The latter is unexpected, since the genepool of cultivated barley is largely depleted of major resistance genes for this fungal pathogen. Therefore, this result needs to be reconfirmed. Moreover, since the leaf rust isolate I 80 is not yet present in Europe, field tests with a mixture of prevalent races are scheduled for 2002, in order to detect genotypes with partial resistance. Regarding BaMMV virus, a series of recessive resistance genes have already been identified (GRANER et al. 2000). In this respect it is interesting to note, that the resistance gene *rym4* was most likely introgressed in high yielding cultivars from the landrace Ragusa initially collected in the area of Dubrovnik. Additional tests are required to determine the number of resistance genes present in the two accessions and to study their allelism to known genes.

In addition to the evaluation for agronomic traits, DNA markers will be used to study the genetic diversity present within this collection and compare its relationship to the Central European barley gene pool.

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Evaluation of genetic resources for resistance to pathogens and pests in the Institute of Epidemiology and Resistance Aschersleben

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Abstract

The Institute of Epidemiology and Resistance as a part of the Federal Centre for Breeding Research on Cultivated Plants has the task to evaluate plant genetic resources for resistance to viruses, bacteria, fungi, pests and virus vectors. The number of accessions evaluated that proved to be resistant is demonstrated. The scientific focus of the Institute of Epidemiology and Resistance is effective resistance research. Resistant cultivars are essential for integrated plant production. The first step in evaluation is the analysis of virulence or aggressiveness in pathogen populations. Strains or isolates of the pathogens are collected and maintained; defined virulences are most useful for resistance evaluation and breeding.

For the characterisation of interactions between pathogens and plants with known resistance genes, population dynamics and epidemiology of pathogens are studied. Strategies of resistance gene management for the use of single genes, of gene combinations and of quantitative resistance to pathogens are developed. The material for evaluation and the development of crop plants with improved resistance to economically important pathogens and for creating new genetic diversity originates from gene banks and selections of plant breeders.

At present, the following host-pathogen systems are investigated (Table 1).

The characterisation of the resistance genes in the selected plant material, the development and improvement of evaluation and resistance screening methods are further tasks of the institute. The number of evaluated and resistant accessions identified is summarised in Table 2. An active cooperation of the Federal Centre for Breeding Research on Cultivated Plants with breeding institutions guarantees the rapid utilisation of the resistant material in the breeding process.

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Tab. 1: Host-pathogen systems investigated

Apple	Fire blight (*Erwinia amylovora*) Spider mites (*Panonynchus ulmi*, *Tetranynchus urticae*) Aphids (*Aphis pomi*) Nectria twig blight (*Nectria galligena*)
Barley	Barley mild mosaic virus, Barley yellow mosaic virus 1 and 2 Barley yellow dwarf virus, Wheat dwarf virus Aphids (*Metopolophium dirhodum*, *Rhopalosiphum maidis*, *R. padi*, *Sitobion avenae*) Leaf rust (*Puccinia hordei*) Net blotch (*Pyrenophora teres*)
Cabbage	Black rot (*Xanthomonas campestris* pv. *campestris*)
Pelargonium	Bacterial Leaf Spot (*Xanthomonas hortorum* pv. *pelargonii*)
Wheat	Barley yellow dwarf virus, Wheat dwarf virus Aphids (see Barley) Leaf rust (*Puccinia triticina*) Eyespot (*Pseudocercosporella herpotrichoides*) Tan spot (*Pyrenophora tritici–repentis*)

Tab. 2: Number of evaluated and resistant accessions

Plant	**Pathogen/Pest**	**Number of Accessions**	
		evaluated	**resistant**
Malus sp.	Bacteria	847	207
	Spider mites	44	3
	Aphids	23	4
Hordeum sp.	Viruses	2200	(BaYMV- complex) 144 (BYDV) 16
	Aphids	505	10
	Fungi	3570	238
Triticum sp.	Aphids	140	18
	Fungi	970	25
Brassica sp.	Bacteria	250	2
Pelargonium sp.	Bacteria	150	10

Improving the utilisation of plant genetic resources in resistance breeding - establishment of a German Network for Cereal Evaluation

H.M. RIEMER [1] and E. SCHLIEPHAKE [2]

Abstract

The project aims at a better transfer and spreading of new or unknown resistance genes into (commercial) breeding programmes to facilitate a more effective use of genetic resources in cereal resistance breeding. A network of more than 20 private German plant breeders and research institutes jointly evaluates pre-selected germplasm of barley and wheat for resistance to the most important fungal and viral pathogens. Commonly used evaluation methods will be refined to be simultaneously applicable to several cereal diseases. An information system for an effective acquisition and provision of the data will be developed by the German Centre for Documentation and Information in Agriculture (ZADI/IBV). The acquired results will be shared first of all amongst the project partners for direct use in the respective breeding programmes and later they will be transferred into BIG (Federal Information System Genetic Resources). This pilot project commenced in January 2001 and is funded by the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL).

Material and methods

Sets consisting of up to 100 genotypes are selected for both crops (wheat, barley), and for both spring and winter forms. The material is chosen based on promising results from previous disease evaluations. Databases from gene banks and research institutions are used as well as variety lists and relevant publications. The sets consist of actual breeding material mainly from BAZ Institutes, as well as foreign varieties and gene bank material.

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Tab. 1: Fungal pathogens screened for, and standards for experiments

Pathogen	Susceptible standards	Resistant (partially resistant) standards
Winter wheat		
Blumeria graminis f. sp. *tritici*	Monopol	Cortez (Mikon)
Drechslera tritici repentis	Bussare	Dream
Fusarium spp.	Darwin	Romanus
Puccinia triticina	Dekan	Travix
Puccinia striiformis	Flair, Mikon	Cortez (Compliment)
Septoria tritici	Renan	Dream
Stagonospora nodorum	Monopol	Petrus
Spring barley		
Blumeria graminis f. sp. *hordei*	Prisma, HOR 7226	Alexis
Drechslera teres	Barke, Pasadena, Compana	Annabell
Puccinia hordei	Alexis, Prisma, L 94	Barke, Hanka
Rhynchosporium secalis	Pasadena, Lenka, Annasofie	Sissy
Winter barley		
Blumeria graminis f. sp. *hordei*	Regina, HJ 171	Verena
Drechslera teres	Krimhild, St. 4046	Camera
Puccinia hordei	Cornelia, Vogelsanger Gold	Carola
Rhynchosporium secalis	Intro, MS Scald	Leonie

The contributing partners may supply the network with their own breeding material. All genotypes tested should carry new or unknown resistance genes or combinations. To characterise the infestation conditions of all sites, at least two standards (susceptible and resistant) for every fungal pathogen are included. Resistance to the most important fungal pathogens of cereals (Table 1) is evaluated; at several sites, virus resistance is screened additionally. Twenty-two private German cereal breeders, mostly organised in the German Federation of Private Plant Breeders (GFP), Bonn, and several research institutes conduct the evaluation trials, score the material, and collect data (Fig. 1).

The sets are evaluated for field resistance in multi-site field trials. Mostly, micro-plots of 1m^2 are used; the trials are set in one or several replications. Every partner screens the whole set for all appearing diseases. Artificial infestation with a pathogen race mixture is recommended according to local infestation conditions and the capabilities of the partners. Replicated scoring over years is planned for the standards and for the most promising candidates only, as well as in the case of missing information, e.g., due to insufficient infestation conditions. Data collection tables prepared

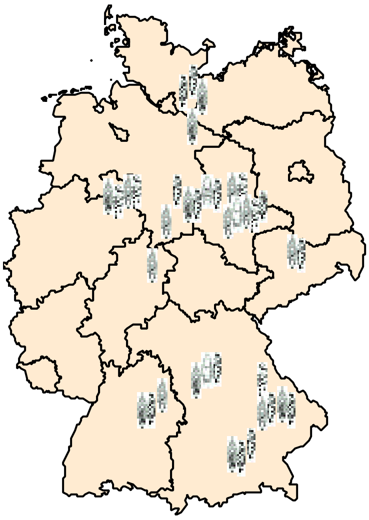

Fig. 1: Test sites for resistance evaluation across Germany

under Microsoft EXCEL to fill in the scorings and relevant pedigree and resistance information are distributed to all partners together with the seed.

The evaluation methods are based on those formulated and already used (WALTHER et al. 1996, http://barley.ipk-gatersleben.de/) and will be further refined. The methods should be simultaneously applicable to several cereal diseases. A score of the percentage of infected leaf or ear area, estimated on each occasion (one value per plot), is preferred compared to the commonly used scoring system from 1 to 9. In contrast to vertical resistance, for a rating of partial resistance, the extent and the development of the infection need to be quantified. Therefore, the area under the disease

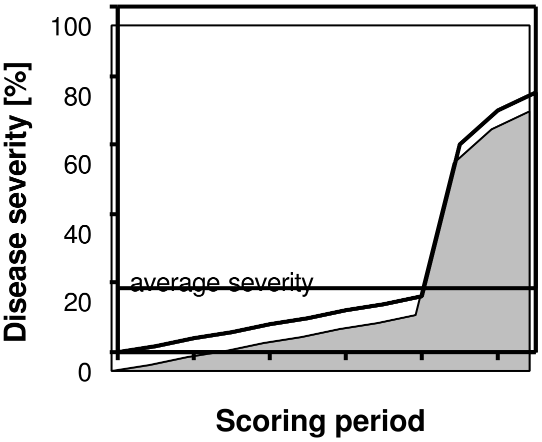

Fig. 2: Area under the disease progress curve

progress curve and the mean disease severity may be determined (Fig. 2). A reliable estimate of the partial resistance of a given genotype requires several scoring dates (WALTHER et al. 1996). The partners are requested to conduct three scorings for every occurring disease; starting, when the infestation becomes apparent and then scoring every seven to 14 days. A statistical analysis of the data is planned, following the methodology described by MOLL (1996).

Comparison is made between the scores of the test candidates and the standards. If no standards are available, conclusions can be drawn from comparisons with environment minimum and maximum values. On the basis of field observations it will be verified, if known PCR markers for different pathogens occur in the tested material. The results are summarised and soon after harvest shared amongst the project partners for direct use in their own breeding programmes. This network-information system for data acquisition, overview, and provision is under development by the German Centre for Documentation and Information in Agriculture (ZADI/IBV, Bonn).

Contracts will officially regulate the rights and duties of the partners; the most important detail is the right of the breeders to use all material screened for their own breeding programmes, and the obligation to score a defined minimum. Thus, the network-information system acts on mutual benefit of all participants.

Scientists of the following institutions are either directly involved in the project or indirectly support it with scientific knowledge on the various pathogens, on obtaining, or multiplying material:

- BAZ, Institute of Epidemiology and Resistance, Aschersleben
- ZADI, Information Centre for Biological Diversity (IBV), Bonn
- BAZ, Institute of Resistance Research and Pathogen Diagnostics, Aschersleben
- BAZ, Plant Genetic Resource Collection, Braunschweig
- Federal Biological Research Centre for Agriculture and Forestry (BBA), Institute for Plant Protection in Field Crops and Grassland, Kleinmachnow
- Bundessortenamt (BSA), Hannover
- Institute of Plant Genetics and Crop Plant Research (IPK), Genebank, Gatersleben

First results and discussion

A prototype of a data base system (http://www.genres.de/eva/) gives information about the network, material tested, and methods. Summarised data of the first growing cycle for spring barley and winter wheat are available for the partners.

Due to insufficient natural infestations, not all diseases could be scored. For spring barley, *Rhynchosporium secalis* did not occur naturally. For winter wheat, the ear diseases (*Fusarium* spp., *Stagonospora nodorum*) and *Drechslera tritici-repentis* were scored only in the BAZ Institute. Insufficient natural infestation may be overcome by more artificial infestation with pathogen race mixtures in the next cycle. Climatic conditions differ between years and between environments – the multi-site screening increases the probability for sufficient and valuable scorings.

Several breeders did not consider it necessary or possible to score more than the usual one or two times, whereas this project requires three scoring times. On average, three scorings were realised in 24% (winter wheat) and 65% (spring barley) of the sites with occurrence of a disease. Some breeders were already satisfied with the occurrence of some interesting genotypes, whereas others would prefer material with several combined resistances or better agronomic value than was presented in the set of the first year. For future screening, the number of partners has been augmented.

The authors expect the network system to become more efficient, when partners get accustomed to the system and more motivated by having found interesting material.

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MOLL, E. (1996): RESI. Assessing partial resistance in cereal cultivars. A SAS application. Version 3.1. In: Reports from the Federal Biological Research Centre for Agriculture and Forestry **374**, 94-126.

WALTHER, U., K. FLATH, E. MOLL, J. PROCHNOW and E. SACHS (2000): Methodological guidelines for the assessment of partial resistance in cultivars or lines with special emphasis on epidemiological aspects. In: Reports from the Federal Biological Research Centre for Agriculture and Forestry **374**, 68-84.

EU Barley Project homepage: http://barley.ipk-gatersleben.de/
EVA project homepage: http://www.genres.de/eva/

Central Register for biological research collections in Germany - ZEFOD

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Abstract

Only occasional overviews and analyses of botanical and zoological research collections in Germany exist at the moment, but individual collections are in various stages of self documentation. The existing data will be combined by ZEFOD systematised and, together with new data, presented via the Internet as an expandable, interactive information network for a broad range of users in science, administration, and the general public. Apart from an overview of collections, the ZEFOD information system will provide a structural and content-oriented description of biological research collections in Germany based on metadata provided by collection holders. To record the metadata, questionnaires have been designed, mailed to the collection holders, and made available via the ZEFOD homepage. Metadata areas covered include data on the institution or collection holder (address, contacts, staff), general information about the collection (taxonomic and geographical foci, state of documentation), and a description of the collection's contents (number of objects, degree of computer recording, number of nomenclatural types).

ZEFOD stands for "Zentralregister biologischer Forschungssammlungen in Deutschland".

Current state of the database of national zoological collections

The questionnaires for zoological collections in museums or universities were mailed in three batches to 214 institutions. The questionnaires for zoological gardens have

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been mailed in November, because these institutes usually have more time to do paper work in winter. By October 9, 2001, 20% of the institutions had answered the questionnaires (42 institutions with 102 collections), 13% announced that they intend to participate, but need more time, and 10% do not hold the sort of collections required for participation in the ZEFOD database. In all 43% of the institutions responded to our initiative within the first four months. A further increase of coverage is expected, because the response rate for the first batch of questionnaires (mailed in June) has reached 82%.

Some of the museums were visited in order to explain the aims of the project and to obtain the data. Similarly several scientific as well as other meetings within the community of collection holders, curators, etc. were attended. Representatives of Naturweb (Austria) and BIODIV (Belgium) were contacted in order to exchange experience with regard to online databases carrying meta information about biological collections. A representative of ISIS (International Species Information System), a database for zoological gardens, was contacted to check the possibility of using some of their data for ZEFOD.

Current state of the database of national botanical collections

Questionnaires were mailed to 70 herbaria. For Botanic Gardens, data from 435 special collections in 71 gardens have already been collected in previous projects (see, e.g., RAUER et al. 2000). The survey for living collections will be based on this information, so the gardens will obtain partly filled-in questionnaires to complete their data in a next step. An Access2000 database application is used for interim data collection and the data existing for Botanical Gardens have been transformed into the ZEFOD data format and integrated into the data bank. The database already accepts queries for different collection characteristics like taxonomy, geography, biotopes, and functional types. It also allows a detailed analysis and shows the amount, variety, and diversity of living plant collections in Germany and different spectra of the representation of diversity in nature and in collections.

To ensure support for the project and to achieve maximum data quality, the Association of Botanical Gardens (VBG) has been informed about the objectives and working plan of ZEFOD. Sixteen Botanic Gardens and six herbaria have already been visited to inform directors and staff about ZEFOD and to give practical support in answering the questionnaire. Moreover, the project has been presented in four meetings within the botanical collection community. Within this audience ZEFOD is now well known and the utility of its aims is widely accepted.

Information technique

The ZEFOD database itself is being implemented as a relational database, optimised to store the complex data resulting from the filled in questionnaires. Data input from these questionnaires is done by routines reading the word files and by off-line input, using interfaces containing ‘classical’ input fields (checkboxes, drop-down lists, etc.). Tools for online-data input are also under development which will help to develop ZEFOD into a permanently sustainable information system. Acceptance of the Internet has to be improved, however, before these tools will be used by all collection holders. Scripts for checking correctness of links to homepages of the institutions are under development to guarantee that the information provided is up-to-date.

One important access path to the information in ZEFOD is the search for taxa by their name. Therefore a database structure to store scientific and common names is under development. The user will also be supported by a thesaurus for querying system.

While data capture will be done through the whole phase of the project, some of the results are already available by querying the online-database. Technically this is realised by using ORACLE 8i and scripts for creating dynamic pages. Access to institution names and places is free but there is temporarily a restricted area for accessing further details. This allows collection holders to check the data before they will be published.

Biological collection information may be provided on the collection metadata level and on the unit (specimen) level. ZEFOD provides metadata for all biological research collections in Germany and will make unit level information access possible. Seen in the international context, ZEFOD is a direct contribution to international initiatives like the ‘Global Taxonomic Initiative’ (GTI), the Convention on Biological Diversity (CBD) and the ‘Global Biodiversity Information Facility’ (GBIF). ZEFOD is the German national node in the ‘Biodiversity Collection Access Service for Europe’ (BioCASE).

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RAUER, G., M. VON DER DRIESCH, P.L. IBISCH, W. LOBIN and W. BARTHLOTT (2000): Beitrag der deutschen Botanischen Gärten zur Erhaltung der Biologischen Vielfalt und Genetischer Ressourcen. - Bonn.

A Biodiversity Collection Access Service for Europe: http://www.biocase.org.
ZEFOD Homepage. http://www.genres.de/zefod.

Federal Information System Genetic Resources (BIG)

S. ROSCHER [1], S. HARRER [1], H.-G. FINK [2], H. KNÜPFFER [3] and TH. STÜTZEL [4]

Introduction

Information requirements on genetic resources are included in the Convention on Biodiversity as well as in the Global Plan of Action for Plant Genetic Resources for Food and Agriculture. In Germany these agreements will be implemented *inter alia* by establishing a set of related internet databases: The Federal Information System Genetic Resources (BIG) integrates databases on the wild flora of Germany, collections of botanical gardens, accessions of the largest German genebank as well as other relevant databases.

Aims and objectives

Taking advantage of synergy effects, the BIG project (http://www.big-flora.de) aims at developing an integrated information system on plant genetic resources that covers a wide range of taxonomic, genetic, biological, ecological, economic and geographical information. It will permit complex searches in heterogeneous, dispersed databases, and facilitates access to the actual germplasm *in situ* and *ex situ*.

BIG collects and provides access to existing data from research institutes associated with German federal and state ministries, and from universities and other research institutions. The information is available for the public sector (for example, nature protection authorities), scientists at universities and other research institutions, as well as for the general public and for non-governmental organisations.

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BIG is also relevant for the private sector, especially for breeding companies and natural raw material industry.

Institutional collaboration

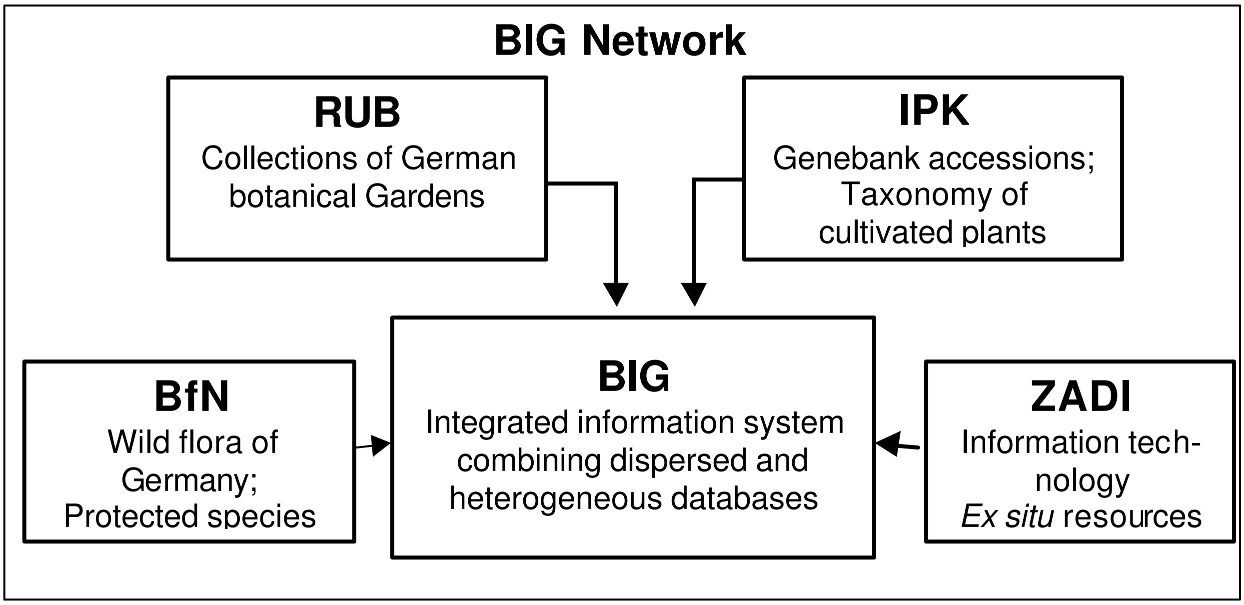
Four German institutions agreed to pool their extensive databases on wild and cultivated plants and their expertise in database management to establish the Federal Information System Genetic Resources (**B**undes**i**nformationssystem **G**enetische Ressourcen, BIG) as an on-line information system on the internet.

The German Federal Agency for Nature Conservation (BfN) at Bonn holds databases on the wild flora (*in situ*), species distribution and ecology, as well as databases on the protection status of plant species according to national and EU legislation. It acts as the German Scientific Authority to CITES, the Convention on International Trade in Endangered Species. On behalf of the Association of Botanical Gardens, the Department for Special Botany and the Botanical Garden of the Ruhr University Bochum (RUB) document the collections (*ex situ*) of botanical gardens in Germany.

The Institute of Plant Genetics and Crop Plant Research (IPK) at Gatersleben performs basic research on cultivated plants. It maintains the collection and database of nearly 100.000 accessions of cultivated plants (*ex situ*), and developed a web database on “Mansfeld‘s Encyclopedia of Agricultural and Horticultural Crops”. The Information Centre for Biological Diversity (IBV) of the German Centre for Agricultural Documentation and Information (ZADI) at Bonn has many years of experience providing information systems on the Internet. Besides a number of crop specific databases it manages the central German database on plant genetic resources on the Internet. The development of BIG is financed by the Federal Ministry of Education and Research (BMBF).

Technical background

For integrating the heterogeneous data sources, BIG follows a mixed approach of ‘Data Warehousing’ and ‘Mediated Approach’. A central repository is used for requests about plant names, which shows detailed information about taxonomic concepts, synonyms, common names, etc. Using this information, the taxa of interest can be chosen, and requests on further detailed information (e.g., holding institutions, evaluation data) are sent to dispersed databases. The user is supported by a thesaurus, containing 120 items covering topics such as breeding characteristics, biology, ecology, distribution, use, access, and references.



To overcome syntactic and semantic differences between the dispersed, heterogeneous databases, BIG follows a mediated approach. The search agent does not communicate directly with the heterogeneous databases but contacts wrappers instead. These wrappers understand the standardised query. They know how to translate this query for the local database and convert the response into a standardised one. The local databases - up to ten at the moment - are queried simultaneously. The BIG-Kernel watches the processes, samples the incoming results and compiles a single answer out of all results before sending it back to the user. For the query as well as for data exchange, XML (Extendable Markup Language) is used.

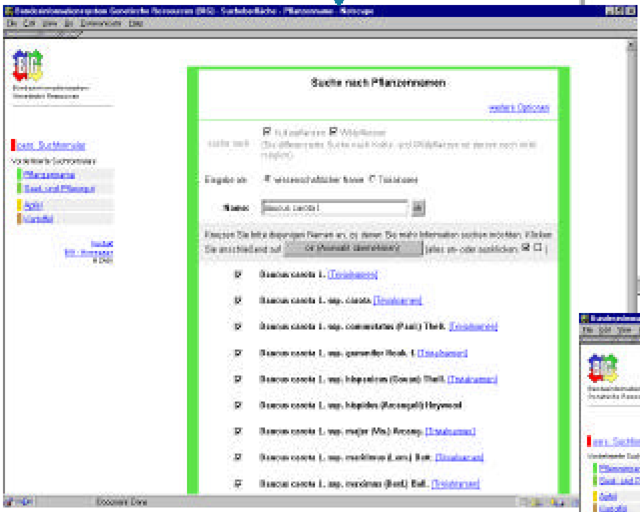
Geographical Information System

For the visualisation and analysis of geo-spatial data, a geographic information system (GIS) is used. Interactive distribution maps for the wild flora of Germany as well as some global area maps are available within BIG. Beyond this, locations of accessions from the local databases given by their coordinates (longitude and latitude) can be converted into geo-spatial data. This happens "on the fly", and accession locations stored in different databases can be compared online. The user can display them together with other thematic maps like topography, climate, soil. Also sample locations can be chosen by ecological regions. The next step will be the integration of gazetteers, so that material can be found by place names, e.g., local names for landscape types.

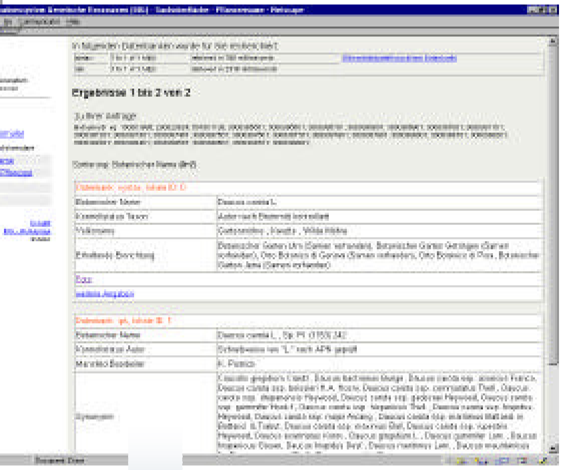
BIG offers an integrated view for a variety of information that is needed in the field of plant genetic resources.

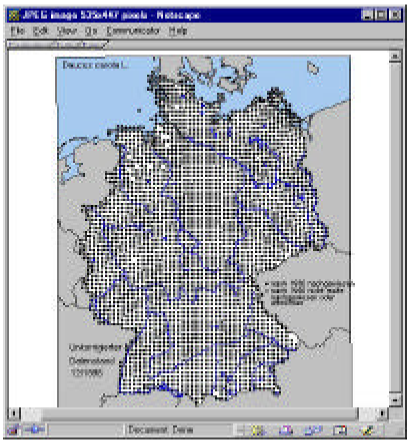
BIG supports the user with a comprehensive thesaurus containing about 120 descriptors. For searching plant names a repository with taxonomic information about wild and cultivated plants can be used (see also BOOS et. al., this volume).

Example: *Daucus carota*



Dispersed and heterogeneous data bases are queried simultaneously

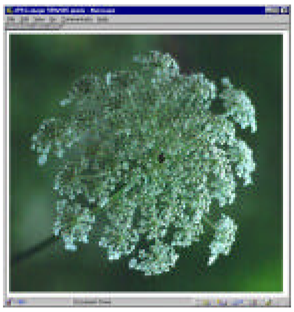




Reference: Florkart, BfN

BIG - search results contain *inter alia* information about use, holding institutions, distribution maps, photographs, ...

Reference: Florkart, Copyright: T. Muer



Reference: Systax, Copyright: St. Müller

Identification of novel interspecific hybrids between *Hordeum vulgare* and *Hordeum bulbosum*

M. SCHOLZ, B. RUGE and B. HACKAUF [1]

Abstract

A crossing programme was initiated to produce interspecific triploid hybrids between diploid *Hordeum vulgare* cultivars (2n = 2x = 14) and some tetraploid *H. bulbosum* accessions (2n = 4x = 28). The hybrid nature of the progeny was confirmed by means of cytological, biochemical and molecular analysis. Most of the plants examined contained 21 chromosomes. The chromosome number of the remainder varied from 19 to 20. This indicates that aneuploid hybrids occurred by elimination of chromosomes. Using isozyme and SSR markers, between two and four *H. bulbosum* chromosomes could be identified in the offspring. To obtain diploid recombinant barley genotypes with introgressed *H. bulbosum* chromatin interspecific hybrids have to be selfed or backcrossed to *H. vulgare*.

Introduction

Hordeum bulbosum belongs to the secondary genepool of *Hordeum*. Since it contains a variety of different resistance genes, *H. bulbosum* has potential value as genetic resource for barley breeding. Recombinants between *H. vulgare* L. and *H. bulbosum* L. have rarely been obtained due to chromosome instability in hybrids, low intergenomic chromosome pairing and low crossing over (PICKERING 1992). Nevertheless, interspecific crosses have resulted in the transfer of novel resistance genes conferring resistance to powdery mildew (KASHA et al. 1996), leaf rust (PICKERING et al. 2000) and the soilborne virus complex (RUGE et al. 2000), respectively. Using molecular markers, the dominantly inherited resistances were mapped on *H. bulbosum* introgressions located on chromosomes 2HL, 2HS and 6HS, respectively. As a starting point for the introgression of *H. bulbosum* genes into barley, triploid hybrids between *H. vulgare* (2n = 14) and *H.*

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bulbosum (2n = 28) are useful because multivalent formation regularly occurs at metaphase-1 (PICKERING 1988).

A crossing programme was initiated to develop novel interspecific hybrids between *H. vulgare* and individual *H. bulbosum* accessions. First results of the hybridisation programme are given in the present report.

Material and methods

Plant material

Eleven plants derived from crosses between the diploid cultivars 'Borwina', 'Nickel' and 'Igri' (2n = 2x = 14) as female parents and three different tetraploid *H. bulbosum* accessions (2n = 4x = 28) as pollinators were analysed. Two *H. bulbosum* parents were from Bulgaria, the third one was from the Botanical Garden Montevideo (Uruguay). All wild species accessions are resistant to barley yellow mosaic virus complex (BaMMV, BaYMV-1 and -2), powdery mildew, leaf rust and snow mold. One of them shows an additional resistance to barley yellow dwarf virus (BYDV) (MICHEL 1996). At 15-20 days after pollination, embryos were isolated and regenerated *in vitro.*

Chromosome counts

Up to four root tips of individual plants were observed to check their somatic chromosome numbers. Chromosome counting was carried out by the standard Feulgen technique.

Isozyme marker analysis

Progenies were electrophoretically assayed for three enzyme loci. The enzyme markers studied were: two leucine aminopeptidase (*Lap2*, *Lap3*) loci and one glutamate oxaloacetate transaminase (*Got1*) locus. *Lap2* is located on chromosome 4H, *Lap3* on chromosome 7H (KOEBNER and MARTIN 1989) and *Got1* is located on chromosome 6H (RUGE et al. unpublished). Isozymes were assessed according to the protocols of HART et al. (1980).

Molecular marker analysis

Interspecific hybrids were identified using EST-derived barley microsatellite markers (RAMSAY et al. 2000). SSR assays were performed as described previously (HACKAUF and WEHLING 2002).

Results and discussion

Interspecific hybridisation between *H. vulgare* and *H. bulbosum* was used to extend genetic variability in barley. Eleven offspring plants were analysed with respect to their hybrid character. Nine out of eleven plants examined displayed 21 chromosomes (Fig. 1).

Fig. 1: 21 chromosomes of a F1 hybrid from a cross between *H. vulgare* and *H. bulbosum*

The occurrence of four plants with 19 and 20 chromosomes, respectively, indicates the elimination of chromosomes. Chromosomal instability is well known in triploid hybrids (PICKERING 1992). Initially, the isozyme markers *Lap2*, *Lap3* and *Got1* were used to identify *H. bulbosum* chromosomes $7H^b$, $4H^b$ and $6H^b$, respectively (Fig. 2). Using these markers, between one and three *H. bulbosum* chromosomes could be identified in different F1 hybrids (Tab.1).

For the majority of analysed SSRs a more efficient amplification could be observed in *H. vulgare* as compared to *H. bulbosum*, possibly due to primer mismatches in the latter species. However, first results for *HvALAAT* and *HvU56406* encoding an alanine aminotransferase and a methyljasmonate-inducible lipoxygenase 2, respectively, demonstrate the potential of SSR markers to identify *H. vulgare* × *H. bulbosum* hybrids (Fig. 3). While *HvALAAT* has previously been mapped on chromosome 1H in barley, the chromosomal localisation of *HvU56406* is still unknown (RAMSAY et al. 2000). Additional mapped SSR should enable to identify each of the seven chromosomes from *H. bulbosum*.

Tab. 1: Cytological, biochemical and molecular verification of interspecific F1-hybrids
(+) allele detectable, (-) allele not detectable, n.d. not determined

Hybrid plant	No. of chromosomes	Isozymes			SSR	
		Got1	*Lap2*	*Lap3*	*HvALAAT*	*HvU56406*
1	21	+	+	+	n.d.	n.d.
2	21	+	+	+	+	+
3	21	+	+	+	+	+
4	19	+	+	+	+	+
5	21	+	+	+	+	+
6	20, 21	-	+	+	+	+
7	20, 21	-	+	-	+	+
8	21	-	+	-	+	+
9	21	-	+	+	+	+
10	21	+	+	-	n.d.	n.d.
11	20	-	+	-	+	+

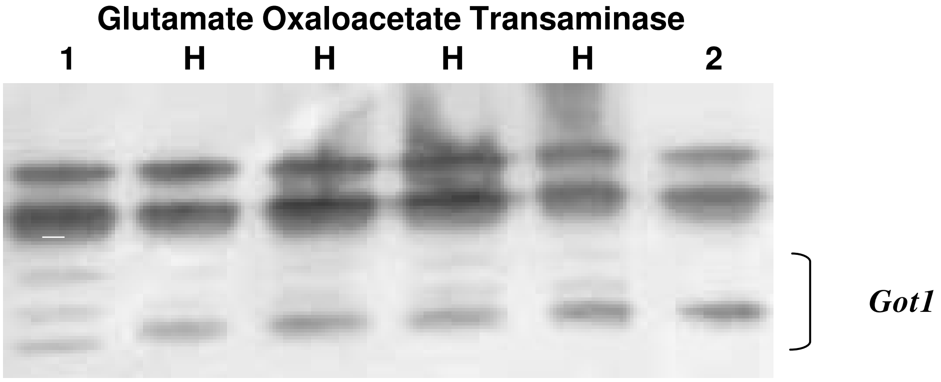

Fig. 2: Identification of interspecific hybrids (H) between *Hordeum vulgare* (1) and *H. bulbosum* (2) by means of *Got1*

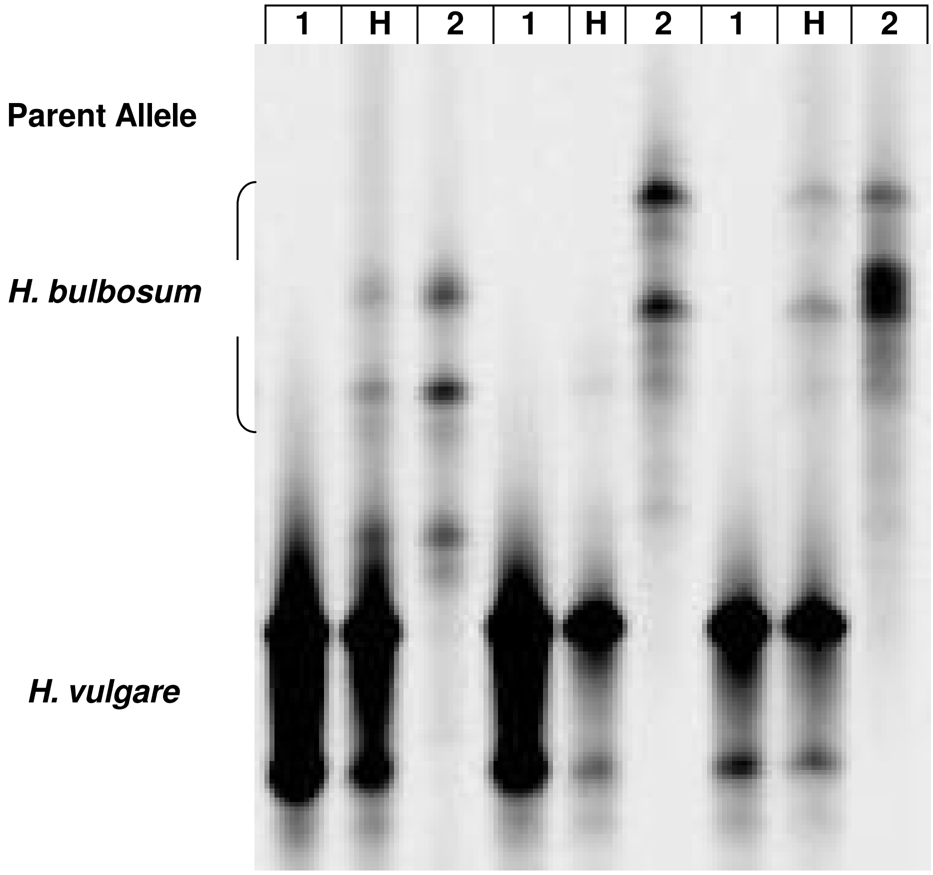

Fig. 3: Identification of interspecific hybrids (H) between *Hordeum vulgare* (1) and *H. bulbosum* (2) by means of *HvU56406*

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Diversity in a clonally propagated crop: morphological characters in garlic compared with existing molecular classifications

A. SENULA and E.R.J. KELLER [1]

Abstract

A subset of 113 garlic accessions from the Gatersleben genebank collection was characterised using 16 morphological characters. The characterisation data were used for principal components and cluster analyses. Comparisons with existing RAPD and isozyme classifications were performed and gave high correlations especially in cases of the *ophioscorodon* and *sativum* groups. The morphological characterisation was used for the selection of a core collection which represents the greatest diversity of garlic in the northern part of Europe.

Introduction

Within the genus *Allium*, garlic is one of the larger crop species well represented in the collection of the Gatersleben gene bank. The garlic gene bank is especially valuable because of the high percentage of original material from collection missions. In the course of an EU-funded GenRes project, a priority subset out of all the Gatersleben accessions has been selected. The main selection criteria were the geographical representation in combination with already documented isozyme and RAPD data (MAASS and KLAAS, 1995). This subset has been characterised during four years by means of morphological markers. It has been introduced into virus-free *in vitro* storage and will be the research base for cryopreservation studies. It has been offered to other research groups and users as a reference collection for further studies on garlic.

Material and methods

The characterisation of the gene bank material has been done in co-ordination with the process of re-formulation of the minimum descriptors prepared for publication by IPGRI.

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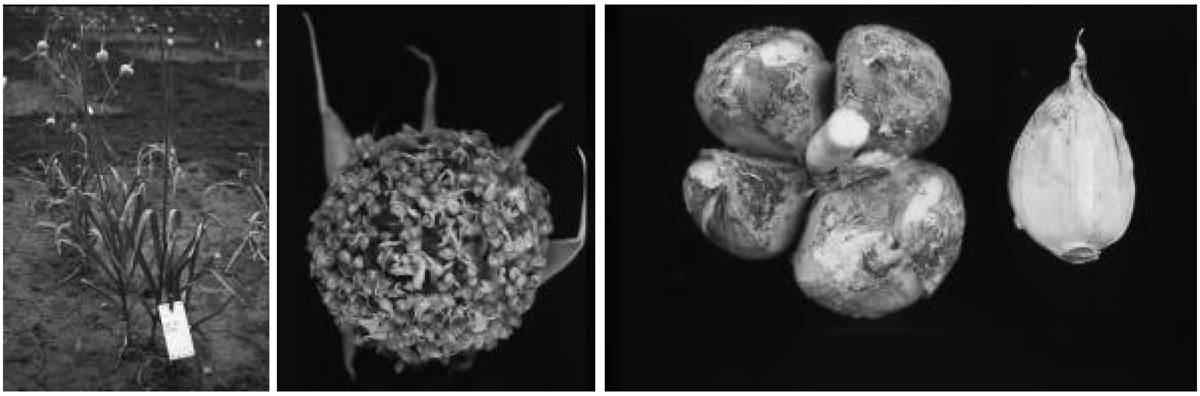

Fig. 1 a-c: Examples for characters used in morphological descriptions of garlic accessions
a: scape; b: PRB/PRFL; c: BSTR

The following 16 descriptors have been used for this study:

BSTR	bulb structure type (Fig. 1c)	PD	pseudostem diameter
BW	bulbil weight	PH	pseudostem height
CC	skin colour of the cloves	PRB	presence of bulbils (Fig. 1b)
HM	harvest maturity	PRFL	presence of flowers (Fig. 1b)
FA	foliage attitude	SCAPE	ability to form scapes (Fig. 1a)
FC	foliage colour	SHSV	side view shape of the compound bulb
NRC	number of cloves per bulb	SHTV	top view shape of full-grown bulbs
OC	outer skin colour of the bulb	SZC	size of the cloves

For precise characterisation, the cloves were planted in field plots with planting distances of 15 cm within the lines and 62 cm between the rows. Of each accession 40 cloves were planted in the first year. For the repeated characterisation 10 cloves per accession were used in the next year. All characterisation data have been arranged in scores of 2 to 6 classes.

Results and discussion

The characterisation of the accessions in two successive years demonstrated similar results concerning the main characterisation parameters such as ability to produce scape, presence of bulbils and flowers, number of cloves, pseudostem height and bulb structure. Intra-clonal variability has been found in the character “Ability to produce scape” especially in the short-stalked forms. In this case, this character varied from scapes sitting only inside the bulb to the break of the bulbils through the leaf sheaths of the pseudostem in various heights from the soil level up to the end of the pseudostem. The characterisation data were used for principal components (Tables 1, 2) and cluster analyses.

Tab. 1: Eigenvalue analysis of 16 morphological characters in garlic

Principal component	eigenvalue	% variability	accumulated variability
1	4.55	28.5	28.5
2	2.04	12.7	41.2
3	1.58	9.9	51.1
4	1.15	7.2	58.3
5	1.11	6.9	65.2

The first five principal components gave eigenvalues greater than 1.0 and explained together 65.2% of the accumulated variation. Correlations with values above / below ±0.6 were considered as most important for that principal component. The first component was associated mainly with SCAPE, BSTR, PRFL, PRB and PH. The second principal component was associated with SZC and BW. The third component was associated with SHSV (Table 2).

Tab. 2: Correlation coefficients of 16 morphological characters

Character	PC 1	PC 2	PC 3	PC 4	PC 5
BSTR	**-0.825**	0	0	0.180	0.175
BW	-0.129	**0.665**	-0.338	-0.508	0
CC	-0.113	0.187	0.483	-0.346	0.305
HM	0.575	-0.249	-0.480	0	0.118
FA	-0.198	0.430	0	0.185	0.110
FC	0.503	-0.169	-0.346	0.149	0.287
NRC	-0.586	-0.159	0	0.335	-0.131
OC	0.323	-0.175	0	0.151	-0.516
PD	0.181	0.692	0	0.379	-0.216
PH	**0.630**	0.285	0	0.471	0
PRB	**0.787**	0	0.352	0	0.169
PRFL	**0.876**	-0.173	0.287	0	0.113
SCAPE	**0.870**	0.115	0.192	-0.277	0
SHSV	0	0.189	**0.694**	0.106	-0.430
SHTV	-0.318	0.145	0.345	0.297	0.547
SZC	0.314	**0.754**	-0.182	0	0.100

The cluster analysis identified five clusters containing between two and 59 accessions per cluster (Figure 2). Accessions of clusters 1 and 2 are characterised by the ability to produce a scape clearly longer than the pseudostem and possessing bulbils in the inflorescence only. Cluster 3 contained only four accessions with a tiny habit. Cluster 4 is characterised by two accessions without visible scape formation, irregular bulb structure and a small size of cloves. Cluster 5 covers mainly accessions which formed a scape shorter than the pseudostem.

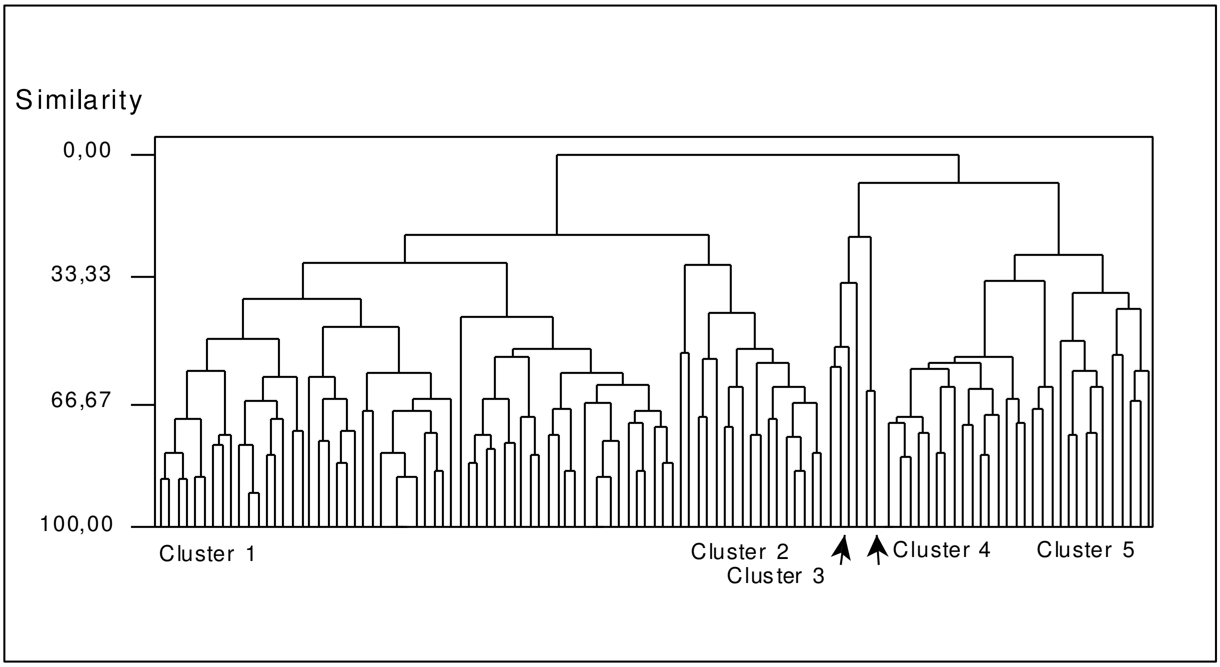

Fig. 2: Cluster analysis of 113 accessions of the garlic collection, calculated with complete linkage method (Euclidean distance)

Several case studies were made to explain the interrelationships between the morphological marker trees and the already existing molecular marker dendrograms. According to MAASS and KLAAS (1995), the more basic (ancestral) groups (the *longicuspis* group) are scattered through their molecular dendrograms which makes them difficult for comparisons, whereas the *ophioscorodon* and *sativum* groups are sufficiently homogeneous to use them for comparisons (Figure 3).

The analyses of the morphological parameters were used to select 25 accessions from the three main clusters 1 (48%), 2 (16%) and 5 (36%). These accessions represent the greatest diversity of garlic in the north of European Union and are the long-day part of the core collection of garlic which has been established using funds of a European project aimed at preserving the genetic diversity of *Allium*.

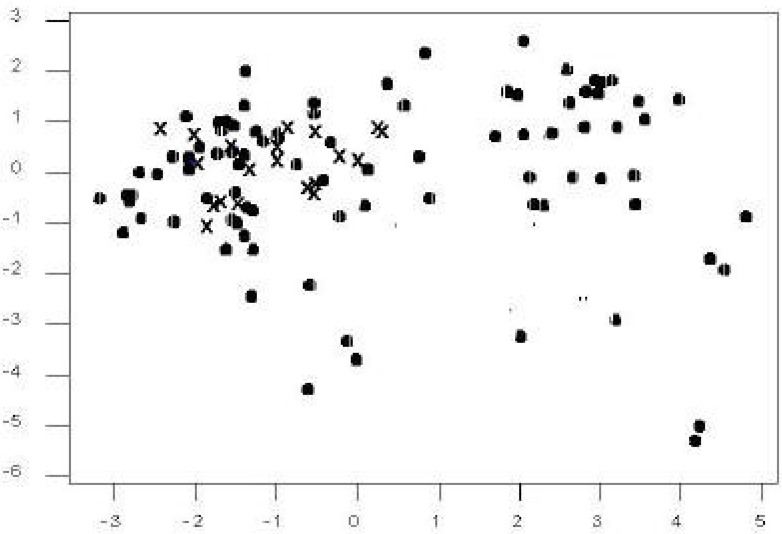

Fig. 3 a: Plot of the first and second principal components derived from analysis of a data set of 16 morphological characters
x - accessions of the *ophioscorodon* group (isozyme/RAPD subgroup III; MAASS and KLAAS, 1995). They are characterised by curled inflorescence stalks, large bulbils and inflated middle spatha parts

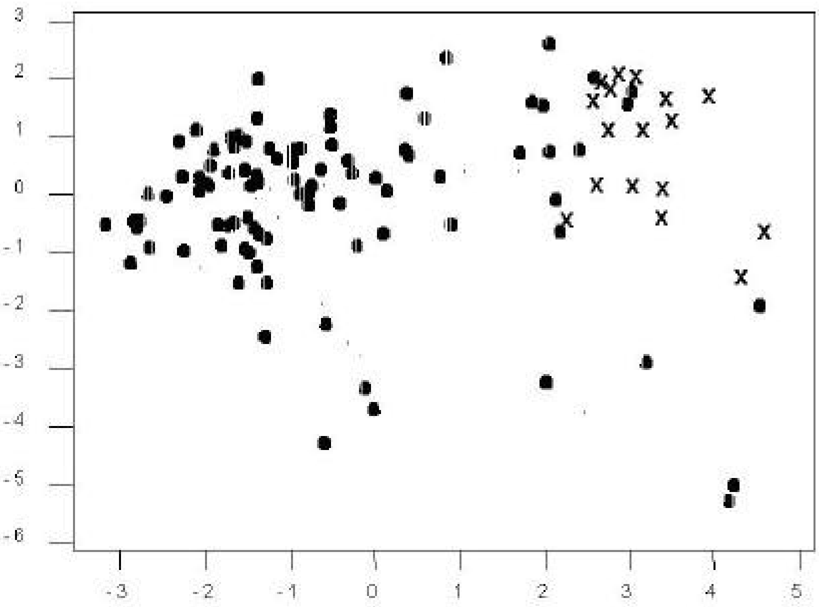

Fig. 3 b: Plot of the first and second principal components derived from analysis of a data set of 16 morphological characters
x - accessions of the *sativum* isozyme/RAPD subgroups II c and d (MAASS and KLAAS, 1995). They are characterised by incomplete scape formation

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Resynthesised *Brassica napus* as a genetic resource in rapeseed improvement for quality and agronomic performance

F. Seyis, W. Friedt and W. Lühs [1]

Abstract

The limited geographic range of oilseed rape (*Brassica napus* L. ssp. *napus*) and intensive breeding has led to a comparatively narrow genetic basis in this crop species. In contrast, *B. rapa* L. (syn. *B. campestris* L.) and *B. oleracea* L. are both highly polymorphic and therefore offer a much broader genetic variability that can be exploited for *B. napus* improvement via interspecific hybridisation ("resynthesis") of the original progenitors assisted by biotechnology. In general, the low yield performance and conventional quality (high erucic acid-high glucosinolates rapeseed, HEAR) of resynthesised *B. napus* is a handicap for the broad use of this novel genepool in modern rapeseed breeding programmes. However, the discovery of lowerucic acid mutants among *B. oleracea* accessions and the development of synthetic rapeseed through wide crosses with respective 0- or 00-quality *B. rapa* genotypes will offer the possibility to use this basic material as a genetic resource for quality and yield improvement in oilseed rape.

Introduction

During the past 50 years, numerous efforts have focussed on exploring "novel" germplasm and developing basic *B. napus* breeding stocks by using genetic resources of *B. rapa* (turnip rape, turnip, Chinese cabbage, Indian sarson, toria, etc.) and *B. oleracea* (kale, cabbage, Brussels sprouts, kohlrabi, cauliflower, sprouting broccoli, wild kale, etc.) for wide hybridisation. The crop species *B. napus*, which encompasses oilseed rape and some fodder crops (ssp. *napus*) as well as rutabaga or swede turnips (ssp. *napobrassica* (L.) Hanelt), is a natural amphidiploid derived from the diploid species *B. rapa* (2n=10, AA) and *B. oleracea* (2n=18, CC) (cf. Diederichsen 2001). Following the strategy of developing novel synthetic *B. napus* forms has provided important basic germplasm for further improvements of seed yield, disease and pest resistance as well as relevant seed quality traits (Song et al. 1993, Becker et al. 1995, Lühs and Friedt 1999, Seyis et al. 2001, Lühs et al. 2001).

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Material and methods

Developing intraspecific hybrids based on resynthesised rapeseed

In the course of an industrial rapeseed breeding programme, spring-type resynthesised HEAR lines (RS lines) were developed and evaluated for agronomic features, such as growth habit, different leaf characters, flowering behaviour and seed yield components (cf. LÜHS and FRIEDT 1999, SEYIS et al. 1999). Nine selected RS lines – derived from interspecific crosses between different cauliflower (*B. oleracea* ssp. *oleracea* convar. *botrytis* var. *botrytis* L.) cultivars ('BK 2256', 'BK 2287', 'BK 3094', 'BK 3096' and 'Venus') and *B. rapa* 'Yellow Sarson' (ssp. *trilocularis* (Roxb.) Hanelt; Y.S.) – as well as the old spring cultivars 'Janetzkis Sommerraps', 'Bronowski' and 'Svalöfs Gulle' were used as male parents (pollinators) in order to develop intraspecific hybrids (cf. pedigree Tab. 1). For hybrid seed production the male sterile double-low lines 'MSL-506c' and 'MSL-510c' (NPZ, Norddeutsche Pflanzenzucht, Hohenlieth, Germany) were grown in the year 2000 under isolation cages together with the high-erucic acid pollinators; pollination was facilitated by bumble bees. The semi-synthetic rapeseed hybrids (TH1-TH18) based on RS lines as well as the conventional test hybrids (TH19-TH24) were analysed for fatty acid composition by gas chromatography. The experimental hybrids (Tab. 1) were tested in the growing season 2001 for yield performance at two locations - the Field Research Station of Rauischholzhausen (near Marburg/Hesse, Germany) and Hohenlieth (NPZ, Hohenlieth, Germany) - and with two replications using the double-low spring rapeseed 'Senator' and the breeding line 'PF 8242/96' as checks.

Tab. 1: Pedigree of the experimental spring hybrids (TH1-TH24) derived from the intraspecific cross MSL line × Pollinator

Female Parent		Male Parent (Pollinator)	
MSL-510c	**MSL-506c**	**RS line / Cultivar**	**Pedigree of RS line**
TH1	TH2	RS 578d	BK 2256 × Y.S.
TH3	TH4	RS 55	Y.S. × BK 2256
TH5	TH6	RS SF 301	Y.S. × BK 3094
TH7	TH8	RS SF 306	Y.S. × BK 3094
TH9	TH10	RS SF 390	Y.S. × BK 3094
TH11	TH12	RS SF 279	Y.S. × BK 3096
-	TH14	RS 232a	BK 2287 × Y.S.
TH15	TH16	RS 16S/5b	Y.S. × BK Venus
TH17	TH18	RS 239b	BK 2287 × Y.S.
TH19	TH20	Janetzkis Sommerraps	Natural rapeseed
TH21	TH22	Bronowski	Natural rapeseed
TH23	TH24	Svaloefs Gulle	Natural rapeseed

Novel synthetic rapeseed with low erucic acid content

Individual zero-erucic *B. oleracea* plants belonging to the three accessions 'Kashirka 202', 'Ladozhskaya' and 'Eisenkopf' (LÜHS et al. 2000) were crossed with different *B. rapa* quality types, viz. 'Asko' (0, spring fodder rape), an apetalous *B. rapa* line and 'Reward' (both 00, yellow-seeded spring type), and two 00-winter type lines ('Q3F' and 'SWSP'). The efficiency of interspecific crosses was aided by embryo rescue. Cuttings from these hybrids were treated with colchicine in order to obtain amphidiploid *B. napus* plants (cf. LÜHS and FRIEDT 1999, SEYIS et al. 2001).

Results and discussion

Resynthesised rapeseed as a resource in hybrid breeding

The experimental hybrids (TH1-TH24) were checked for hybridity; as expected all of them showed an intermediate seed oil quality with erucic acid contents ranging from 8.3 to 40.4%. The results of the yield trial are presented in Fig. 1. Regarding relative seed yield ('Senator'=100, 30.0 dt/ha), the left streaky columns represent the hybrids derived from the female line 'MSL 506c', while the right grey columns represent the hybrids belonging to 'MSL 510c'. The average seed yield of the 25 genotypes was 33.6 dt/ha. Hybrids developed from the female parent 'MSL-506c' tended to give higher seed yields compared to hybrids from 'MSL-510c'. The three synthetic lines 'RS 578d' ('BK 2256' × 'Y.S.'), 'RS SF 306' ('Y.S.' × 'BK 3094') and 'RS 239b' ('BK 2287' × 'Y.S.'), whose experimental hybrids showed the best results (Fig. 1), are considered as promising material.

Novel synthetic rapeseed with low erucic acid content

With regard to oilseed rape, current double-low (canola) breeding material seems to be closely related and intensive quality breeding has also contributed to narrow the genetic base of this crop species (VOSS et al. 1998). On the other hand, the availability of effective hybridisation control systems has enabled the development of hybrid cultivars and has led to a demand for maximum diversity among breeding material. Due to its poor agronomic performance and seed quality, the establishment of a new genepool based on artificial *B. napus* is limited. One strategy to exploit this novel germplasm in rapeseed improvement with minimum losses neither of seed quality nor genetic divergence is seen in new resynthesis experiments using zero-erucic *B. oleracea* mutants, which we have identified previously (LÜHS *et al.* 2000). In a preliminary experiment we developed 16 amphihaploid hybrids from the reciprocal crosses *B. rapa* 'Asko' × zero-erucic acid *B. oleracea* forms. Seed oil analysis of the first individual hybrid ('Kashirka 202' × 'Asko') revealed a zero-erucic acid phenotype as expected (SEYIS et al. 2001). The results of the *B. napus* resynthesis experiments using *B. rapa* cultivars other than 'Asko' as female parent are summarised in Tab. 1. Most of amphihaploid individuals *in vitro* were obtained in these cases where the apetalous line was used as *B. rapa* parent (Tab. 1).

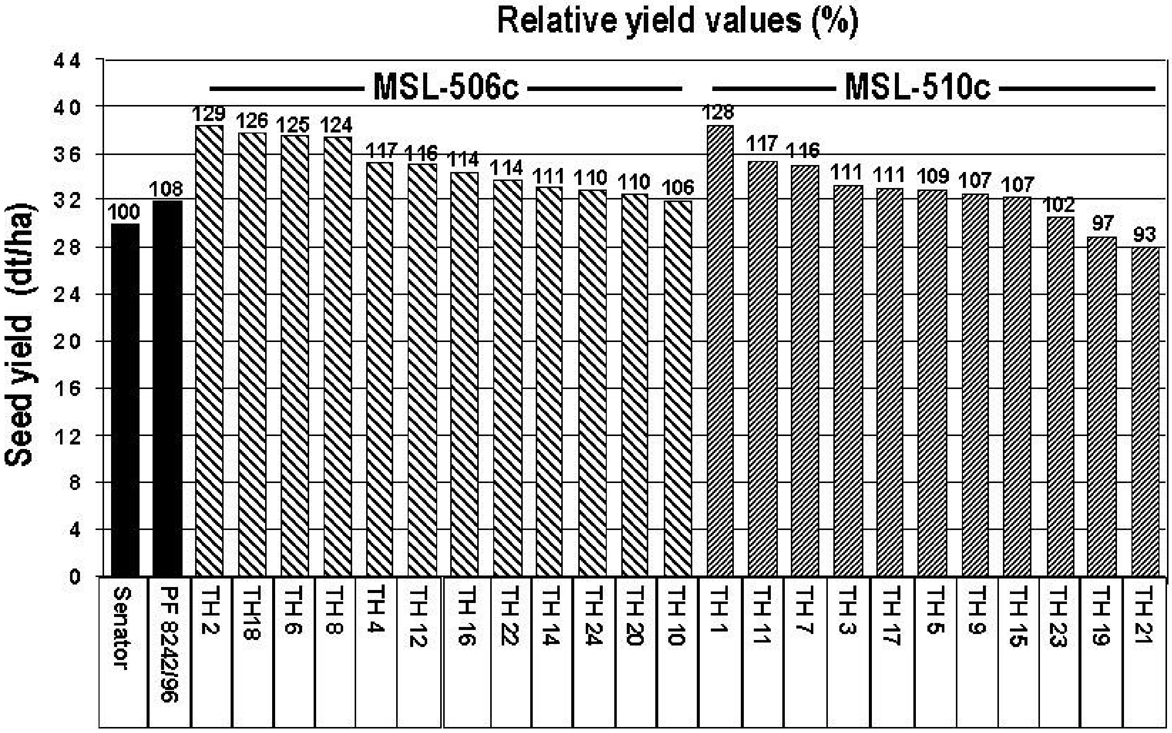

Fig. 1: Yield performance of experimental hybrids (TH1-TH18) based on resynthesised *Brassica napus* pollinator lines (RS lines, cf. Tab. 1) compared to natural rapeseed including conventional test hybrids (TH19-TH24) and the check varieties 'Senator' (rel. 100=30.0 dt/ha) and 'PF 8242/96'

Tab. 2: Efficiency of *Brassica rapa* × *B. oleracea* hybridisation *in vitro*

Cross combination *B. rapa* × *B. oleracea*	**No. of pollinated buds (A)**	**No. of prepared ovules (B)**	**No. of obtained hybrids (C)**	**Success rate (%)**	
				(C/B) × 100 Regeneration ability *in vitro*	**(C/A) × 100 Crossability**
'Apetalous turnip rape' × 'Kashirka'	654	2,333	188	8.1	28.7
'Reward' × 'Kashirka'	583	1,007	11	1.1	1.9
'Apetalous turnip rape' × 'Ladozhskaya'	626	2,757	222	8.1	35.5
'Reward' × 'Ladozhskaya'	505	759	21	2.8	4.2
Q3F × 'Ladozhskaya'	163	289	16	5.5	9.8
'SWSP' × 'Ladozhskaya'	182	262	10	3.8	5.5

Conclusion

Because of its inferior quality and low yield potential, the use of resynthesised *B. napus* is usually restricted to the development of semi-synthetic rapeseed forms, which must be further improved by extensive backcross breeding.

Although the developed spring hybrids (MSL line × RS line) show a conventional HEAR seed quality, their yield performance demonstrates the genetic diversity and the potential of this basic material in hybrid breeding. In order to overcome this limitation, novel synthetic *B. napus* germplasm was developed conferring a unique low-erucic acid gene to oilseed rape.

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Temperate homegardens of small alpine farmers in Eastern Tyrol (Austria): Their value for maintaining and enhancing biodiversity[1]

B. VOGL-LUKASSER[2] and CH. R. VOGL[3]

Eastern Tyrol (Lienz district) is located in the Eastern Alps of Austria and characterised by a multifunctional cultural and natural landscape. Homegardens are an integral part of this mountainous landscape. An ethnobotanical survey was carried out in 1997 and 1998 in 196 gardens on farms, at elevations between 600 and 1.600 m above sea level (VOGL-LUKASSER 2000; VOGL-LUKASSER et al. 2002).

Subsistence farming was primarily based on arable crops, alpine hay meadows and grazing grounds until the 1970s. Homegardens provided only a small number of species (mean ca. 10 per garden); throughout the region in total 51 species were grown. Since the 1970s, cultivation of field vegetables, cereals and fibre crops is in decline. As a parallel process, women actively enrich diversity in gardens and a remarkable increase of the number of species grown can be observed (mean 42 per garden; throughout the region in total 587). Species are introduced not only from the surrounding agroecosystems, where biodiversity is eroding, but also from natural ecosystems or markets. In addition, women retain the main part of species and varieties traditionally grown in homegardens.

Of these 587 species, 79 have some kind of endangered status according to the Austrian *Red List* (NIKLFELD and SCHRATT-EHRENDORFER 1999). 39 *cultivated species* can be classified, according to LOHMEYER (1981), as *cultivation in danger of decline* in Central Europe. Traditional perennial garden species were passed on by predecessors at 77% of the farms. Local varieties of 16 annual or biannual species are passed on as seeds and are cultivated in gardens and fields at 21% of the farms examined.

Homegardens in Eastern Tyrol can be seen as a place of importance for the *in situ* conservation of traditional farming techniques of certain plant genetic resources.

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[1] Full text will be published in: Proceedings of the workshop “Contribution of home gardens to *in situ* conservation of plant genetic resources in farming systems”, 17-19 July 2001, Witzenhausen, Germany. IPGRI, Rome, Italy.

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