The management of germplasm of wild relatives of crop plants at Gatersleben

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Abstract

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Large collections of wild relatives of crop plant have been established at the Gatersleben genebank as a consequence of the growing demands of breeding research and plant breeding. A specific approach to such collections was necessary, reviewing and developing the possibilities of genebanks. The first 'monographic treatment of wild plant collections' describing the genus *Aegilops* from the perspective of genebank aspects appeared in 1980. Other examples that meeti breeders' demands are *Hordeum* and *Secale*. Two special cases are described for *Datura*, with a collection stemming from biochemical and taxonomic-morphological research, and *Agrostemma*, a weed showing convergent evolution and with economic possibilities, but endangered by developing agricultural techniques and methods. Once in the genebank the material has to be evaluated to allow more effective use in plant breeding.

Introduction

The Gatersleben genebank has a long tradition as a part of the Institute of Plant Genetics and Crop Plant Research. From the very foundation of the institute in 1943 different basic scientific disciplines, such as genetics, biochemistry and biophysics, were included as scientific departments that used material from the genebank for their studies (Hammer 1993a). Taxonomy, in fact, was looking afterwhat was the nucleus of the present large genebank as part of its department – systematics and collections. All these basic disciplines and especially taxonomy were also interested in the wild relatives of crop plants, the investigation of evolutionary pathways during domestication and how to make use of their wider range of variation. In this way small collections of wild relatives of crop plants were built up. They gave a first impression of the problems of maintaining wild plants *ex situ* and it was possible to gain some experience.

In the sixties and especially in the seventies a marked tendency was observed in plant breeding — the inclusion of more and more wild relatives of crop plants into the programmes (Harlan 1976, Hawkes 1977). One result was an increase of requests to genebanks for such material. Accordingly, the genebank collections had to meet the demands of the breeders. Material was included mainly on the level of the primary genepool (Harlan & de Wet 1971) for the practical reason of the easy inclusion of such material into crossing programmes. With increasing possibilities of producing wide crosses the secondary and even tertiary genepools also became of more interest. A practical solution was to consider all the species in a genus.

Accordingly, research in the Gatersleben genebank hasbeen carried out mainly at the generic level.

Case reports

The specific Gatersleben approach will be demonstrated using some case examples which have been detailed so as to provide an understanding of the problems and prospects of *ex situ* conservation of wild plants. The first three examples concern material which is actually needed for plant breeding (*Aegilops*, *Hordeum*, *Secale*). The fourth example (*Datura*) derived from biochemical and taxonomic work in the Gatersleben institute for which a special collection was built up. Later on this collection was transferred to the genebank where it has been further developed. The last example is taken from the special approach apllied to weeds (*Agrostemma*). Crop mimics are dependent on human agricultural activities. They cannot survive outside more or less traditional agricultural systems and have, therefore, to be preserved in the same way as landraces of crops –in some cases 'on farm', but mostly in genebanks. They are potential crops in many cases (see also Vavilov's 1926 theory on secondary crops).

Aegilops

Aegilops is related to wheat and a great number of cases have been reported documenting the transfer of genes from the wild relative to the crop, particularly for resistance characters. All species belong to the primary gene pool of *Triticum* (von Bothmer & al. 1992) but there are marked differences in the possibilities of gene transfer to wheat. The genus comprises 21 species (Hammer 1980a). All of them are present in the Gatersleben collection (Table 1). For the classification and correct determination of the material, which are important preconditions for the handling of the accessions in the genebank and for information and exchange, older monographs were available (Zukovskij 1928, Eig 1929) which had to be updated (Hammer 1980a), also with regard to the infraspecific classification. The infraspecific level is of particular importance for genebanks because it provides an insight into the variation and can be, in many cases, the basis for separating lines which is a method to avoid loss by genetic drift under the conditions of *ex situ* reproduction (see Hammer 1993b). Most of the accessions need some vernalization. They grow very well under Gatersleben conditions and provide a good harvest of spikes. Because of the long lasting maturing period and the easily shattering spikes a continuous harvesting over a period of time is necessary.

Table 1. Material of the genus *Aegilops* in the Gatersleben genebank.

A. bicornis (Forssk.) Jaub. & Spach.	6
A. biuncialis Vis.	39
A. columnaris	9
A. comosa Sibth. &t Sm.	
subsp. *comosa*	1
subsp. *heldreichii* (Boiss.) Eig	5
A. crassa Boiss.	
subsp. *crassa*	14
subsp. *vavilovii* Zhuk.	19
A. cylindrica Host	84
A. geniculata Roth	190
A. juvenalis (Thell.) Eig	7
A. kotschyi Boiss.	8
A. longissima (Schweinf. & Muschl.) Eig	
subsp. *longissima*	23
subsp. *sharonensis* (Eig) Hammer	16
A. markgrafii (Greuter) Hammer	60
A. mutica Boiss.	
var. *loliacea* (Jaub. & Sp.) Eig	3
var. *mutica*	5
A. neglecta Req. ex Bertol.	
subsp. *neglecta*	29
subsp. *recta* (Zhuk.) Hammer	34
A. peregrina (Hackel) Maire et Weiller	
subsp. *cylindrostachys* (Eig & Feinbrun) Hammer	2
subsp. *peregrina*	9
A. searsii Feldman et Kislev ex Hammer	13
A. speltoides Tausch	38
subsp. *speltoides*	
subsp. *ligustica* (Savign.) Zhuk.	39
A. tauschii Coss.	171
A. triuncialis L.	159
A. umbellulata Zhuk.	
subsp. *transcaucasica* Dorof. & Migusch.	4
subsp. *umbellulata*	11
A. uniaristata Vis.	4
A. ventricosa Tausch	34
Hybrids	6
Total	**1042**

The breeding system varies from autogamy to allogamy and deserved a special study because relevant information was lacking in literature (Hammer 1980b). In cross pollinators isolation has to be secured and sufficient size of populations may be difficult to obtain. The storing of seeds presents no problems. *Aegilops* was the first genus used to demonstrated the specific needs for genebanking of wild plants at Gatersleben and a new approach was made for a 'monographical treatment of collection of wild plants' (Hammer 1980b).

Hordeum

Hordeum is a genus comprising about 40 taxa (Jacobsen & von Bothmer 1992). Only the wild progenitor *H. spontaneum* (*H. vulgare* subsp. *agriocrithon*) and related morphotypes as *Hordeum* × *lagunculiforme* belong to the primary genepool of *H. vulgare*, the cultivated barley. The secondary genepool is composed of *H. bulbosum*, and all the other wild barleys form the tertiary genepool (von Bothmer & al. 1992). For the species of the secondary and tertiary genepools a recent systematic treatment is available giving also indications for the maintainence of the material in genebanks, e.g. breeding system (von Bothmer & al. 1991). The wild and weedy relatives of the primary gene pool lack a modern systematic treatment especially at the infraspecific level. Therefore, in Table 2, the traditional designations are used. The main propagation problem with this material has to do with the disarticulating spikes and the breeding system. They are, for the most part, autogamous but more open-flowering than most of the cultivated barley accessions and, therefore, a certain isolation, preferably by distance, is necessary (Hammer 1984a). Most of the accessions have a vernalization requirement.

Table 2. Wild and weedy relatives of the primary genepool of barley in the Gatersleben genebank.

H. spontaneum Koch var. *bactrianum* Vav.		7
var. *ischnatherum* Coss.		45
var. *spontaneum*		121
var. *transcaspicum* Vav.		15
H. agriocrithon Åberg var. *agriocrithon*		15
var. *dawoense* Åberg		9
var. *paradoxon* Schiem.		13
H. × *lagunculiforme* (Bacht.) Bacht. ex Nikif.		45
	Total	**270**

Only a relatively restricted collection is available, in in terms of number of accessions per species, for the secondary and tertiary genepools; this was initiated to get a deeper insight into the variation found in the reproductive systems (Hammer & Matzk 1993) and the rejuvenation of the material which is not yet solved completely, especially as regards foreign pollinators.

Secale

The genus comprises four species and several subspecies (Hammer & al. 1987). They belong to the primary genepool of cultivated rye, *S. cereale* subsp. *cereale*, except *S. sylvestre*, which has to be considered as part of the secondary genepool (Table 3). As the material is easily crossed with cultivated rye, accessions from the collections are often intercrossed and good material is difficult to obtain. Introgression of weedy subspecies with landraces was common *in situ*, but there is a marked decrease of landrace cultivation and also in the distribution of the weedy and wild forms. Isolation is required for most of the accessions. Only three taxa are autogamous – *S. sylvestre*, *S. strictum* subsp. *africanum* and *S. vavilovii* (Hammer 1990). The others have to be treated as cross pollinators, i.e. they have to be isolated from each other and also from cultivated rye which has only a few autogamous accessions (*S. turkestanicum* = *S. cereale* subsp. *rigidum*). Most accessions of *S. strictum* are perennial. It is difficult to obtain larger populations and a long term isolation is necessary which limits the intake of a larger number of stocks. As in cultivated rye the viability of the seeds of the other taxa is also restricted.

Table 3. Wild and weedy relatives of rye in the Gatersleben genebank.

Secale cereale L. subsp. *afghanicum* (Vav.) Hammer	16
subsp. *ancestrale* Zhuk.	7
subsp. *segetale* Zhuk.	34
subsp. *dighoricum* Vav.	2
Secale strictum (Presl) Presl subsp. *africanum* (Stapf) Hammer	2
subsp. *anatolicum* (Boiss.) Hammer	3
subsp. *ciliatoglume* (Boiss.) Hammer	1
subsp. *kuprijanovii* (Grossh.) Hammer	18
subsp. *strictum*	26
Secale sylvestre Host	15
Secale vavilovii Grossheim	2
Total	**126**

Datura

Datura (excl. sect. *Brugmansia*) comprises about 10 species (Avery & al. 1959). Some taxa from Mexico are still under investigation and could eventually add some further species. Several species are used as medicinal plants but the efforts of plant breeders to improve the material are still rather limited. The collection at Gatersleben was created in connection with morphological-systematic (Danert 1958) and biochemical studies (Mothes & Romeike 1952). Later, after finishing those studies, the collection came into the genebank and was continuously monitored and completed there (Table 4). This is one of several cases where already existing larger collections had to be taken over by the genebank, taking into account the efforts involved in their establishment and the results already obtained with the material, that may also become important for other users.

In *Datura* problems for genebank work mainly derive from the breeding system and seed characteristics. *Datura* is pollinated by insects. There are also species which tend towards autogamy. Only the well expressed cases of autogamy as in *Datura stramonium*, *Datura ferox* and *Datura leichhardtii* need no strong isolation of the accessions within these species. A deeper study is necessary because in *Datura stramonium* for example there are races tending also towards allogamy (Hammer & al. 1983). All the other material has to be considered as cross-pollinators and isolation in cages or cabins is necessary for different races within one species. Pollinating insects should be available. Thus, the breeding and use of insects is necessary as described for allogamous entomophilous material in the Gatersleben genebank, e.g. solitary bees and hover flies (Gladis 1989). Seeds of *Datura* have a good storage ability. But the dormancy sometimes strongly expressed can give the impression that the viability of seeds has been already lost. A treatment of the seeds of *Datura ceratocaula* and *Datura ferox* with gibberellic acid before germination is necessary to obtain suitable results. This method can also be recommended for the other species (Hammer & al. 1983).

Table 4. Material of *Datura* (excl. sect. *Brugmansia*) in the Gatersleben genebank.

D. ferox L.	6
D. inoxia Mill.	26
D. metel L.	
var. *fastuosa* (L.) Danert	8
var. *metel*	2
var. *muricata* (Bernh.) Danert	3
var. *rubra* (Bernh.) Danert	1
D. quercifolia H.B.K.	1
D. stramonium L.	
var. *godronii* Danert	5
var. *inermis* (Jacq.) Timm	1
var. *stramonium* Hammer	
f. *labilis*	1
f. *stramonium*	60
var. *tatula* (L.) Torr.	
f. *bernhardii* (Lundstr.) Danert	2
f. *tatula* (L.) Torr.	23
D. wrightii hort. ex Regel	17
Other species	10
Total	**166**

Agrostemma

Agrostemma represents another kind of situation. The genus contains only two species. Agricultural use is limited to a few cases, mostly as a technical crop. *A. githago* was formerly an important weed butis now nearly extinct. Over centuries or even millenia this weed of the convergent evolutionary type co-adapted to different crops (e.g. wheat, flax, buckwheat). The result was a co-domesticated weed showing the typical domestication syndrome (Hammer 1984b). These weeds, as a rule, are not able to survive outside the agroecosystems but there they have been so severely damaged by modern agricultural treatment, that some of them, like *A. githago*, only survived in fields of traditional landraces. In connection with these landraces *A. githago* was collected by the Gatersleben genebank and a rich collection of material wasbe obtained (table 5). It seems to be necessary to incorporate these co-domesticated weeds into the genebanks to conserve a larger part of their variation which is useful for further use in agriculture (e.g. as new raw material or for ecological farming). As *A. githago*, though a weed, has largelydeveloped the characteristics of a cultivated plant, no special methods had to be devised to maintain them, (Hammer & al. 1982). It should be noted that there are winter and spring types. *A. githago* is a self-pollinator.

Table 5. Material of *Agrostemma* in the Gatersleben genebank.

A. brachylobum (Fenzl) Hammer		7
A. githago L.		
	var. *githago*	148
A. githago L.		
	var. *linicolum* (Terech.) Hammer	3
A.githago L.		
	var. *macrospermum* (Levina) Hammer	23
	Total	**181**

Evaluation

As has been shown, the main reason for holding collections of wild relatives of crops is the availability and use of this material for plant breeding. For this purpose evaluation is necessary. The genus *Aegilops* is taken as an example for demonstrating this process. Secondary evaluation of the Gatersleben material is carried out jointly by the genebank and specialists in phytopathology, biochemistry, biophysics etc. from other institutes. The phytopathological evaluation of the *Aegilops* collection has been carried out either with colleagues from the University of Halle (Germany) or the Research Institute of Crop Production Prague (Czech Republic).

The results are shown in Table 6. All species show some resistance. Only one species, *A. speltoides*, showed resistance against all diseases investigated. In other species, as in *A. tauschii*, there is generally a low percentage of resistances against all but one disease. This is the advantage of a rather large collection of this species (see Table 1). A large number of accessions increases the probability for finding resistant material which is of special interest in *A. tauschii*, the D-genome donor of bread wheat, because of the possibilities of enhancing the incorporation of resistance into *Triticum aestivum* in more easily than from other *Aegilops* species. A fuller discussion of evolutionary pathways within the genus, genome-dependent resistance expressions and other details is presented by Hammer (1987).

Table 6. Disease resistances in the Gatersleben *Aegilops* collection as percentages of the available accessions.

	Erysiphe graminis[1]	*Puccinia recondita*[1]	*Puccinia striiformis*[2]	*Puccinia graminis*[2]	*Pseudocercosporella herpotrichoides*[3]	*Septoria nodorum*[4]
A. bicornis	83	8	0	0	33	0
A. biuncialis	100	50	50	0	11	0
A. columnaris	89	60	22	0	11	0
A. comosa	50	57	100	0	0	0
A. crassa	13	0	0	0	5	0
A. cylindrica	54	35	0	0	0	15
A. geniculata	92	29	52	4	6	0
A. juvenalis	67	0	0	0	0	0
A. kotschyi	100	13	20	0	20	0
A. longissima	96	23	23	6	0	0
A. markgrafii	71	71	80	60	0	0
A. mutica	100	0	33	0	0	0
A. neglecta	96	100	82	14	0	22
A. peregrina	91	74	33	0	20	0
A. searsii	0	67	35	0	0	0
A. speltoides	78	91	83	81	6	2
A. tauschii	27	8	8	12	2	0
A. triuncialis	87	55	35	0	20	4
A. umbellulata	83	84	29	0	0	13
A. uniaristata	0	0	75	25	0	50
A. ventricosa	75	0	46	0	29	0
All species	66	40	33	14	6	4

[1]after Hammer (1987)
[2]after Valkoun & al. (1985)
[3]after Groll & al. (1985)
[4]after Frauenstein & Hammer (1985)

Conclusions

Only a few cases of special collections of wild relatives of crop plants in the Gatersleben genebank could be discussed in this paper. There are many other examples as *Raphanus* (Pistrick 1987) and *Brassica* (Gladis & Hammer 1990) and the large collection of *Allium* (Hanelt & al. 1992) maintained by the Taxonomy Department of IPK should also be mentioned here.

Our examples have been chosen to illustrate cases in which specific efforts have been made for a monographic treatment of such collections, focussing on genebank approaches and activities (*Aegilops*, *Secale*, *Datura*, *Agrostemma*). More work should be done into this direction.

The different examples show that a number of problems has to be studied and solved for a successful establishment of larger wild plant collections in genebanks, as e.g.:

- taxonomy also including the infraspecific level,
- cultivation methods,
- breeding systems,
- populations sizes,
- storage of seeds and other organs (including *in vitro*).

Evaluation is necessary so as tomake better use of the material in plant breeding programmes.

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