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Potato Collecting Expedition to Bolivia and the Importance of Bolivian Germplasm for Plant Breeding*)

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With 1 figure and 3 tables

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Abstract

A potato collecting expedition to Bolivia was organized in 1980. Three teams, including potato scientists from South America and Europe, sampled intensively primitive cultivars and wild species of the potato in all geographical distribution areas of Bolivia. The outcome of the expedition is presented and as a result of the collecting activities four previously undescribed species and one subspecies were collected. The taxonomy and the breeding value of the Bolivian species are discussed.

Key words: *Solanum* — potato — genetic resources — wild species and primitive forms — potato taxonomy — breeding value

Although a number of expeditions had been organized in the past to collect potato germplasm in Bolivia, the living material available in the international gene banks was still rather limited (VAN SOEST 1981). Nearly all previously organized expeditions collected in more than one country and their sampling was predominantly conducted along the main roads. Other expeditions concentrated on herbarium material or cultivated species only. In comparison to the collecting activities in Argentina, Peru and Mexico the potato genetic resources of Bolivia have been somewhat neglected. For instance, before the expedition only 280 accessions of 22 species were available in gene banks, whereas more than 800 accessions of 36 species are now maintained in the "German-Netherlands Potato Collection".

*) Dedicated to Prof. Dr. Dr. h.c. H. KUCKUCK on the occasion of his 80th birthday.

The aims of the expedition can be summarized as follows:

— to broaden the genetic base of Bolivian germplasm in gene banks and to make new material available to plant breeders;
— to sample in areas where no collections had been made previously or where previously collected material had not survived;
— to promote biosystematic, evolutionary and other studies on this important group of species.

Organization and participants

The expedition was organized by the "German-Netherlands Potato Department" of the Gene Bank in the Federal Research Center for Agriculture Braunschweig-Völkenrode (FAL) [a cooperation between the Institut für Pflanzenbau und Pflanzenzüchtung der FAL (Director: Prof. Dr. M. DAMBROTH), Federal Republic of Germany, and the Stichting voor Plantenveredeling (SVP) (Director: Dr. Ir. H. LAMBERTS), the Netherlands] and the University of Birmingham, Department of Plant Biology, Birmingham (UK). The funding of the two teams of the German-Netherlands Potato Department was obtained from the Foundation for Agricultural Plant Breeding (SVP), Wageningen, the Netherlands; the Federal Ministry of Economic Cooperation (BMZ), Bonn, Federal Republic of Germany; and the International Potato Center (CIP), Lima, Peru. The University of Birmingham team was funded entirely by CIP.

To ensure efficient organization, close links were established with the following institutions:

— International Potato Center (CIP), Lima, Peru.
— Ministry of Agriculture of Bolivia (MACA — Ministerio de Asuntos Campesinos y Agropecuarios), La Paz/Cochabamba, Bolivia.
— Instituto Boliviano de Tecnología Agropecuaria (IBTA), Cochabamba, Bolivia.
— Consortium for International Development (CID), La Paz/Cochabamba, Bolivia.

All important geographical distribution areas of wild and cultivated potatoes in Bolivia were explored by three teams, each team consisting of three scientists and a driver, from 18th February to 5th April, 1980.

Team one, led by Ir. L. J. M. VAN SOEST, and including — at different periods — representatives from CIP (Dr. K. A. OKADA, Dr. J. LANDEO and Dr. Z. HUAMÁN), IBTA (Ing. C. ALARCÓN and Ing. R. CLAURE) and CID (Dr. R. W. HOOPES), collected mainly in the departments of La Paz and Oruro.

Team two, led by Prof. J. G. HAWKES with the collaboration of Mr. J. P. HJERTING (Copenhagen, Denmark) and including an agronomist from IBTA (Ing. I. AVILÉS), collected mainly in the departments of Cochabamba and Santa Cruz.

Team three, led by Prof. W. HONDELMANN, with the collaboration of Dr. D. ASTLEY (NVRS, U.K.) and representatives of IBTA (Ing. A. MOREIRA and Ing. G. CAERO) collected in the departments of Potosí, Chuquisaca and Tarija.

Thus, important areas of the altiplano, the semi-tropical Yungas, the eastern valleys and the semi-tropical foothills were covered by this expedition.

The three collecting teams travelled in total more than 20 000 km. The areas covered and routes followed are shown in *Figure 1*.

A further visit was made by one of us (Prof. J. G. HAWKES) in 1981, and additional living material was obtained.

Collecting results

The wild species were collected from natural or semi-natural vegetation, with the exception of some accessions found as weeds of cultivation. The primitive cultivated material was sampled from three different sources: cultivated fields, markets and some accessions from the IBTA collection in Tora-

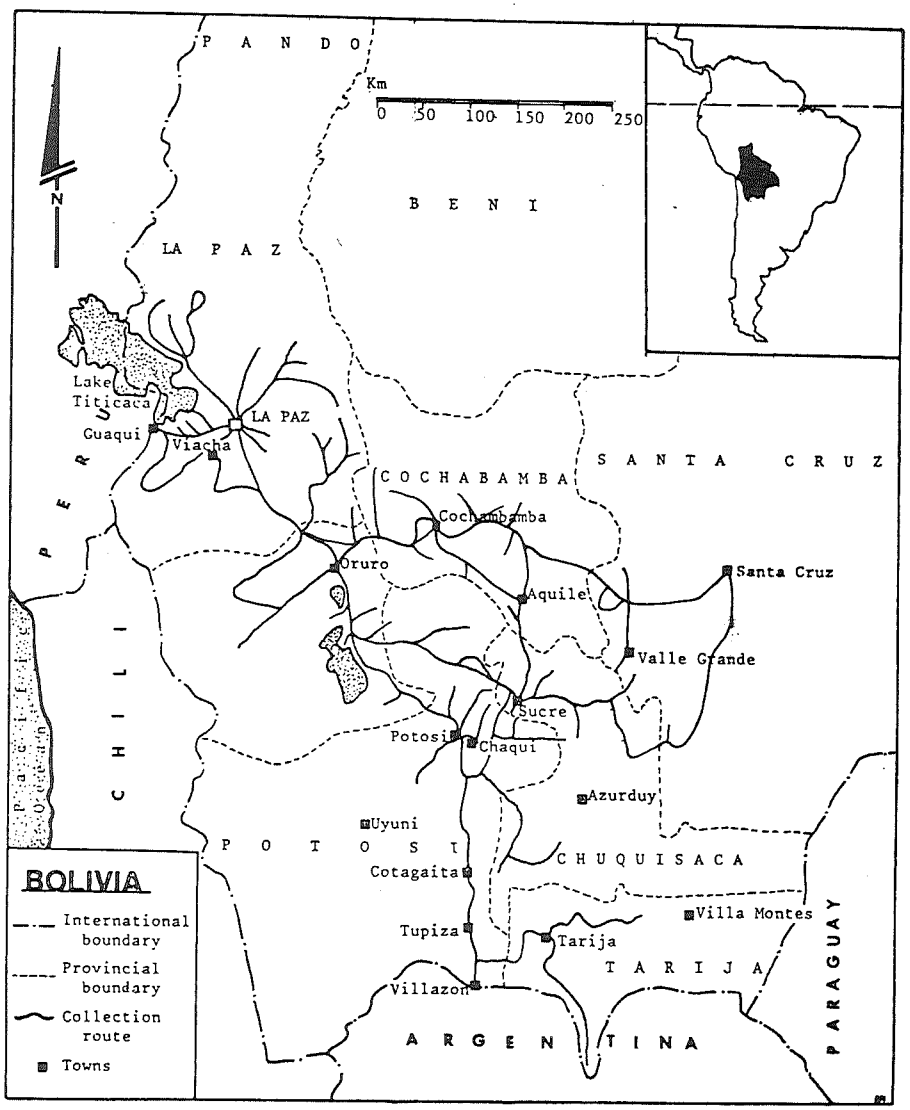

Fig. 1 Potato collection route

lapa. To obtain optimal genetic diversity, sampling was done as far as possible on a population basis.

In practice each accession consisted of several berries, collected from different plants of the local population, taken in as random a manner as possible. Thus each collection contains an enormous number of genotypes. When seeds were not available tubers or even living plants were collected for rejuvenation by IBTA in Bolivia or CIP in Peru. From interesting collections, particularly from those species which were difficult to identify in the field and from the rare species, such as *S. yungasense*, all species in the series *Circaeifolia* and

Tab. 1 Number of samples of primitive cultivars and wild species collected by the three teams in Bolivia

	Team 1	Team 2	Team 3	Others*)	Total
	Primitive cultivars				
Seed samples	47	—	5	43	95
Tuber collections	41	1	—	—	42
Living plants	—	1	—	—	1
Herbarium specimens	6	—	—	—	6
	Wild species				
Seed samples	140	68	163	—	371
Tuber collections	2	14	—	—	16
Living plants	—	53	—	—	53
Herbarium specimens	109	146	125	—	380

*) Received from the IBTA germplasm collection at Toralapa (Bolivia).

several rare species of the series *Tuberosa*, herbarium collections were also made. Sometimes, when living material could not be collected through lack of tubers or seeds only herbarium material was taken. Thus the locality of the collection was registered so that it could be of importance for future expeditions.

The final results of all three collecting teams listed, separately under wild species and primitive cultivars, are presented in *Table 1*. A total of 588 living collections was made; however, the samples listed in *Table 1* add up to more than this number since in several instances combinations of seed, tuber and living plant samples were made from the same collections. Some of the collected living plants could not be rejuvenated and other accessions did not germinate. A total of 536 accessions are now maintained in the "German-Netherlands Potato Collection". Herbarium collections also, were made from some material collected in the living state.

All species reported to occur in Bolivia are listed in *Table 2*. Those collected during the expedition of 1980 are marked. It shows that the three expedition teams collected more than 5 accessions from 21 species. However, from several species including *S. acaule, S. megistacrolobum, S. leptophyes, S. sparsipilum, S.* × *sucrense* and the cultivated species *S. tuberosum* ssp. *andigena* more than 15 accessions were collected. Two species *S.* × *doddsii* and *S. gandarillasii* were not found. Some species not marked in *Table 2* are probably all synonyms of other existing species which were collected.

Under the cultivated species more than 100 accessions of *S. tuberosum* ssp. *andigena* and approximately 20 accessions of *S. stenotomum* were sampled. Only a few collections of *S. ajanhuiri, S. curtilobum* and *S. phureja* were made. From the species *S. juzepczukii* only herbarium material was collected, as this triploid species is sterile and no tubers were available.

Some accessions collected as field weeds turned out to be "forms" of *S. tuberosum* ssp. *andigena* or *S. stenotomum*. These "semi" primitive forms with vernacular names like Kcoa Choque, Lelecoya and Taihua are probably

escapes or weedy segregates of earlier cultivations. Near Sorata (north of La Paz) in an area without potato cultivation these forms were found in maize fields. They may be of interest to potato breeders as they have survived a period of natural selection. It was said that some of these forms were occasionally eaten.

Several hybrids were found under the collected accessions (e.g. *S. berthaultii* × *S. tarijense* and *S. violaceimarmoratum* × *S. yungasense*). In areas where *S. acaule* grows together with diploid species, triploids (e.g. *S. acaule* × *S. toralapanum*) were found in certain collections.

Tab. 2 Bolivian potatoes and species collected in 1980

Series/Species	2n	Series/Species	2n
VI. Commersoniana		*XVIIIa. Tuberosa* (wild)	
1. *S. chacoense**	24	18. *S. canasense*° (?)	24
2. *S. tarijense**	24	19. *S. candolleanum*°	24
3. *S. yungasense*°	24	20. *S. colominense* (Syn)	?
VII. Circaeifolia		21. *S.* × *doddsii*	?
4. *S. capsicibaccatum**	24	22. *S. gandarillasii*	24
5. *S. circaeifolium* ssp. *circaeifolium*°	24	23. *S. gourlayi**	24, 48
ssp. *quimense** ssp. nov.	24	24. *S. leptophyes**	24
6. *S. soestii*° sp. nov.	24	25. *S.* × *liriunianum* (Syn)	?
VIII. Conicibaccata		26. *S. microdontum* ssp. *microdontum**	24
7. *S. violaceimarmoratum**	24	ssp. *gigantophyllum*°	24
X. Acaulia		27. *S. mollepujroense* (Syn)	?
8. *S. acaule**	48	28. *S. neocardenasii*° sp. nov.	?
XIV. Cuneoalata		29. *S. okadae** sp. nov.	24
9. *S. infundibuliforme*°	24	30. *S. oplocense**	24, 48, 72
XV. Megistacroloba		31. *S. pachytrichum*°	24?
10. *S. boliviense**	24	32. *S. sparsipilum**	24
11. *S. megistacrolobum**	24	33. *S.* × *sucrense**	48
12. *S. toralapanum**	24	34. *S. torrecillasense* (Syn)	24?
XVIIIa. Tuberosa (wild)		35. *S. vidaurrei*°	24
13. *S. achacachense*°	?	36. *S. virgultorum*°	24
14. *S. alandiae**	24?	*XVIIIb. Tuberosa* (cultivated)	
15. *S. avilesii*° sp. nov.	?	37. *S.* × *ajanhuiri*°	24
16. *S. berthaultii**	24	38. *S.* × *chaucha*	36
17. *S. brevicaule**	24	39. *S.* × *curtilobum*°	60
		40. *S.* × *juzepczukii*	36
		41. *S. phureja*°	24
		42. *S. stenotonum**	24
		43. *S. tuberosum* ssp. *andigena**	48

* 5 or more accessions collected; ° less than 5 accessions collected.

Notes: (a) Not all collections of living material survived; (b) Those marked (Syn) are now synonyms of other previously described species; (c) For other species see text.

Taxonomy of the Bolivian potato species

The potatoes of Bolivia are a highly diverse group of species belonging to seven distinct taxonomic series, as follows:

VI. Commersoniana

1. *S. chacoense*. This very widespread species, which is so well-known and common in Argentina, is rare in Bolivia and here reaches its northern limits. A few collections were made.

2. *S. tarijense* is related to *S. chacoense* and was described originally from specimens collected in Tarija; it is much more common than *S. chacoense* and spreads also into north-west Argentina. It is distinguished from the glabrous or sparingly pubescent *S. chacoense* by its dense covering of short glands. *S. tarijense* was collected many times during the expedition.

3. *S. yungasense*. Whereas *S. chacoense* and *S. tarijense* possess white stellate flowers those of *S. yungasense* are pale creamy-yellow and its stem wings are broad and straight. Besides the typically glabrous forms of this species from the northern Yungas area near La Paz, other more pubescent collections were obtained further to the south-east by the expedition members. The existence of these southern forms was hitherto unexpected.

VII. Circaeifolia

All species in this series possess the typical creamy white stellate flowers and narrow conical sharply pointed berries that are unknown in any other group of wild potatoes. Although they are interfertile, we have so far had no success in crossing them with species outside series *Circaeifolia*.

4. *S. capsicibaccatum* is widespread in the Cochabamba region and many collections were made. Before the 1980 expedition only this species and *S. circaeifolium* had been discovered in series *Circaeifolia*. Because the 1980 expedition went to many hitherto poorly known regions two new taxa were discovered.

5. *S. circaeifolium* in its typical form occurs only near Sorata, north of La Paz. However, a distinct subspecies has now been discovered further south. This is subspecies *quimense* from the Inquisivi and Independencia regions, occurring also as far east as the area of Pojo on the road between Cochabamba and Santa Cruz.

6. *S. soestii*. This new species, collected twice only, from the Inquisivi region, is related to the other two but has very narrow leaflets.

VIII. Conicibaccata

7. *S. violaceimarmoratum* is the most southerly of the chain of species in this series which begins in Central Mexico. The northerly ones are tetraploid and even hexaploid, but *S. violaceimarmoratum* is diploid, in common with many Peruvian species in the series. The ovate-conical blunt-ended berries

clearly distinguish members of this series from those of *Circaeifolia*, and the flowers are generally pentagonal to rotate and purple, rather than stellate and white. Several collections, both from the La Paz and the Cochabamba regions were made.

X. Acaulia

8. *S. acaule* is a widespread species, which spreads from north-west Argentina to northern Peru and is very common in the high mountains of Bolivia. Strangely enough it does not extend further to the east than Koari, near Toralapa, Cochabamba department, in the eastern branch of the Andes which extends from Cochabamba towards Santa Cruz. Only the subspecies *acaule* is known in Bolivia. Many collections of this species were made during the expedition.

XIV. Cuneoalata

9. *S. infundibuliforme.* This species is much more common in Argentina than it is in Bolivia. The narrow leaf lobes and wedge-shaped rachis wings are very distinctive. We found it only a few times, and then only in Potosí department.

XV. Megistacroloba

Extensive collections of the species in this series were made, and a new one, as yet undescribed, was discovered.

10. *S. boliviense* is adapted to the drier regions in the valley systems around Sucre and does not overlap in its distribution with the other two species. It was well-collected in 1980 and is distinguished from them by the clearly defined lateral leaflets.

11. *S. megistacrolobum* was collected frequently on the high plateaux and the mountain ranges not immediately facing the rain-bearing winds from the Amazon basin.

12. *S. toralapanum* seems better adapted to a higher rainfall and was found on the wetter eastern slopes of the Andean massif; many collections were made, particularly in the Cochabamba area.

XVIIIa. Tuberosa (wild)

About 23 Bolivian wild species are to be found in this series and we list them here alphabetically:

13. *S. achacachense* seems to be confined to the high mountains between Achacachi and Sorata, north of La Paz where several collections were made. It is a low-growing species with rather large flowers.

14. *S. alandiae* was collected a great deal during the expedition. It possesses a rather well-defined distribution area east of Cochabamba and north of Sucre, being hardly found outside Cochabamba department though just occurring in Santa Cruz. It seems to be most closely related to *S. microdontum.*

15. *S. avilesii.* This is an interesting new species, so far found only near Valle Grande in Santa Cruz department. The leaves are typically covered with a soft, dense velvety pubescence but although some features remind one of *S. vernei* from Argentina. The two species are very distinct.

16. *S. berthaultii* is a very abundant species of the higher eastern valleys of Cochabamba and Chuquisaca departments, and a wide range of material was collected. It often forms natural hybrids with *S. tarijense* and is well known for its long glandular hairs that protect it from insect attack.

17. *S. brevicaule* is widespread in the Cochabamba and Sierra Tunari regions but does not spread into the main Andean massif. Many collections were made of this species.

18. *S. canasense* just extends into northern Bolivia near Lake Titicaca from southern Peru, where it is quite common. We made only one collection.

19. *S. candolleanum* was described some time ago but has not been found outside the region of Sorata, north of La Paz, where it is quite abundant, and where several collections were made.

20. *S. colominense.* This is a taxonomic synonym of *S. brevicaule.*

21. *S.* × *doddsii* is a naturally occurring hybrid between *S. chacoense* and *S. alandiae* that has been found only in one locality.

22. *S. gandarillasii* is adapted to the low dry thorn-scrub areas in the eastern foothills of the Andes and is a very distinct species. In 1980 the rainfall in those regions was very low and in consequence this species was not found.

23. *S. gourlayi.* This low-growing high mountain species has its main centre of diversity in north-west Argentina but spreads northwards into Bolivia, mainly as a tetraploid cytotype.

24. *S. leptophyes.* This is a widespread species occurring in the high Andes of Bolivia from La Paz, southwards. It is closely related to *S. gourlayi* though it is apparently always a diploid in Bolivia. Further study is needed to elucidate the position of these two taxa. Both *S. leptophyes* and *S. gourlayi* were collected abundantly on the 1980 expedition.

25. *S.* × *liriunianum.* This is derived from a naturally occurring hybrid of *S. brevicaule* and *S. sparsipilum* but since it seems to be closest to *S. sparsipilum* it is classed as a synonym of that species. It was collected from Liriuni, near Cochabamba on several previous expeditions.

26. *S. microdontum.* The two subspecies, which are well-known in Argentina, namely, *microdontum* and *gigantophyllum,* are known also in Bolivia, each with its fairly clearly defined distribution area. Many biotypes possess one or two pairs of lateral leaflets, a feature that seems particularly frequent in ssp. *microdontum.* Many collections were made, in 1980 particularly of the rather common ssp. *microdontum.* A much greater distribution of *S. microdontum* was discovered in 1980, when material not very far south of La Paz was found.

27. *S. mollepujroense*. This species seems to be a taxonomic synonym of *S. sparsipilum* and was collected only once.

28. *S. neocardenasii* is a new and very distinct species, discovered by us only once near Comarapa in Sta. Cruz department. It possesses the glandular pubescence of *S. berthaultii* but has a very different corolla and other features. It may well prove to be of considerable interest to breeders by virtue of the long sticky glandular hairs, thickly covering the whole plant.

29. *S. okadae* is another new species, of which we made several collections in the Inquisivi, Independencia and Morochata regions. It also occurs in north-west Argentina. The species shows many similarities to *S. microdontum* but can clearly be distinguished from it.

30. *S. oplocense* is a species with diploid, tetraploid and hexaploid cytotypes, of which is in Bolivia the tetraploid one by far the commonest. We made several collections of this species, chiefly in Potosí department.

31. *S. pachytrichum*. We made several collections of this little-known species but more study is required before we can be certain of its affinities.

32. *S. sparsipilum*. Many collections were made of this very well-known and useful weed species which is found distributed from Cochabamba department northwards into southern Peru.

33. *S.* × *sucrense* is a common weed species that seems to have been formed as a hybrid between tetraploid *S. oplocense* and *S. tuberosum* ssp. *andigena*. It is widely distributed in Chuquisaca and Potosí departments and many collections of it were made.

34. *S. torrecillasense*. This is a taxonomic synonym of *S. alandiae* and was collected twice during the expedition.

35. *S. vidaurrei* is a rare species, found in the extreme south of the country, but only once during the present expedition.

36. *S. virgultorum*. This has been up to now a very enigmatic species, known only from one collection near Sorata. However, from a careful study of the type specimen in Geneva it became clear that other materials collected by us in the Inquisivi and Cochabamba regions also belonged to *S. virgultorum*, even though it has never been found again in the type locality.

XVIIIb. Tuberosa (cultivated)

Most of the cultivated species also occur in Bolivia and collections were made to add to the already existing germplasm in store at Braunschweig, CIP, and elsewhere.

37. *S.* × *ajanhuiri* is a frost-resistant diploid cultigen resulting from natural crosses between *S. stenotomum* and *S. megistacrolobum*. It is chiefly confined to the La Paz and Oruro regions where a few collections were made during the expedition.

38. *S.* × *chaucha* is the name given to the triploid hybrids between *S. tuberosum* ssp. *andigena* and *S. stenotomum*. A few of these featured in the collections.

39. *S.* × *curtilobum* is a frost-resistant pentaploid cultigen produced from natural crosses between *S. juzepczukii* and ssp. *andigena* and occurring at high altitudes. It was not collected to any great extent.

40. *S.* × *juzepczukii* is another frost-resistant natural hybrid, resulting from *S. acaule* × *S. stenotomum* crosses. No living material of this sterile hybrid was collected.

41. *S. phureja*. This is another diploid species, closely related to *S. stenotomum* and possessing a short maturity cycle and not tuber dormancy. A number of collections were made in the La Paz-Sorata region.

42. *S. stenotomum*. Quite a number of samples of this diploid cultivated species were collected during the expedition.

43. *S. tuberosum* ssp. *andigena*. A large number of seed and tuber samples was made of this important subspecies of the common cultivated potato.

Additional notes on wild species

During the last few years several additional Bolivian taxa have come to our notice, described by Prof. C. OCHOA of the International Potato Centre. Unfortunately, material of these has not been made available to us for study, and we can thus only list them here:

S. flavoviridens Ochoa (Dept. La Paz),
S. litusinum Ochoa (Dept. Santa Cruz),
S. capsicibaccatum Card. var. *latifoliolatum* Ochoa,
S. infundibuliforme Phil. var. *albiflorum* Ochoa.

We would also like to mention here our newly-described species *S. neorossii* from Argentina, very close indeed to the southern Bolivian border. It has been collected on various previous expeditions and may well spread into Bolivia, even though it has not yet been found in that country.

Another species which occurs in Argentina close to the Bolivian border is *S. vernei*. This also might be found north of the border one day. Unfortunately, there is no easy access to the region where *S. neorossii* and *S. vernei* might perhaps occur in southern Bolivia, and their presence or absence cannot yet be verified.

Breeding value of Bolivian Solanum species

The importance of Bolivian potato germplasm to plant breeders has been known for many years. Both wild species and primitive cultivars have been evaluated for valuable characters. Potato cyst nematode resistance is one of the most important properties detected in material from Bolivia. ELLENBY (1952) and TOXOPEUS and HUIJSMAN (1952) reported *Globodera rostochiensis* resistance (gene H_1) in the *Andigena* clone CPC 1673. This clone has been widely used in potato breeding and several cultivars with the H_1 gene are now commercially available. The original accession of CPC 1673 was collected near La Paz; under the name of 'Polo'. Further screening (Ross and HUIJSMAN

1969 and HUIJSMAN et al. 1972) revealed resistance to both *G. rostochiensis* and *G. pallida* in several wild species as well as in the primitive cultigen *S. tuberosum* ssp. *andigena* from Bolivia.

Tolerance to frost is found in several wild species and primitive cultivars from Bolivia. *S. acaule,* a tetraploid wild species, distributed between 2600—4500 m and its triploid derivative *S. juzepczukii,* cultivated at high altitudes, are both well known for their frost tolerance. Several *S. tuberosum* ssp. *andigena* introductions from Bolivia were included in the adaptation programmes of tetraploid cultivated South American potatoes (PLAISTED 1972). In Pentlandfield, Scotland, "Neo-Tuberosum" has been developed from a sample of mainly Bolivian and south Peruvian *S. tuberosum* ssp. *andigena* introductions (GLENDINNING 1975).

It is impossible to deal in detail here with all the useful properties found in *Solanum* species from Bolivia. Therefore an attempt has been made to group together the important properties found in the 7 series. The information used was collected from the following sources: COCKERHAM (1956), ESTRADA (1977), Anon. (1979/1980), GIBSON (1979), HAWKES (1958), HAWKES and HJERTING (1969), HERMSEN and VERDENIUS (1971), ROSS and HUIJSMAN (1969), ROSS (1979), ROTHACKER (1961 and 1968), ROSS and ROWE (1969), VAN SOEST and SEIDEWITZ (1981), some of it based on work on the Bolivian species occurring in surrounding countries.

VI. Commersoniana

An important group of species in which a high degree of non-specific late blight resistance has been reported. *Verticillium* wilt and wart resistance were found in *S. chacoense* and *S. tarijense.* Blackleg resistance was detected in accessions of *S. chacoense.* The latter species, but particularly *S. tarijense,* have properties to protect themselves against insects (e.g. colorado beetle, mites, leaf hopper and aphids). This may have some influence on their degree of resistance to insect-transmitted virus diseases such as leaf roll. In accessions of *S. chacoense* necrotic response to potato virus X (PVX) and PVA, immunity to PVY and PVA and non-specific resistance to PVX and leaf-roll have been discovered. *S. chacoense* is well-known for its biochemical properties. The starch and protein content of certain accessions is above average. In Bolivia the three species of this series are adapted to medium high altitudes (1000—2000 m), in warm sometimes dry but also humid climates. Therefore, they may possess heat and drought tolerance properties. *S. yungasense* grows in the subtropical Yungas with high rainfall and high humidity. It may possibly possess genes for adaptation of the potato to the tropical lowlands.

VII. Circaeifolia

The species in this series have not been common in gene banks and have therefore not been very frequently evaluated. Late blight resistance has been detected in some species and recently cyst nematode resistance was found in several accessions of *S. capsicibaccatum* and *S. circaeifolium* ssp. *quimense.*

VIII. Conicibaccata

S. violaceimarmoratum, the only representative of this series in Bolivia, is not very well-known. It is reported to have a certain degree of resistance to the colorado beetle. As it grows in humid mountain forests, for instance on the upper border of the Yungas, it may possess similar genes to those of *S. yungasense* for adaptation to the humid tropical lowlands. Hybrids between these two species have been found.

X. Acaulia

This polymorphic species is widely distributed in Bolivia at sometimes very high altitudes. It is the most frost resistant tuber-bearing *Solanum* and this character was transferred into the cultivated species *S. juzepczukii* and *S. curtilobum* after natural hybridization. Several resistance to fungi such as late and early blight, wart, common scab, powdery scab and *Verticillium* wilt are reported in accessions of *S. acaule.* Ring rot, bacteria wilt and blackleg resistances are also known in this species. Resistances to many virus diseases have been found in *S. acaule* of which the extreme resistance to potato virus X (PVX) is available in modern varieties. Besides cyst nematode resistance against different pathotypes (Ro_1, Pa_2 and Pa_3), root knot nematode resistance was detected in *S. acaule* as well.

XIV. Cuneoalata

The only representative of this Series in Bolivia, *S. infundibuliforme,* is more common in Argentina. A high degree of resistance to blackleg, a necrotic response to PVA and hypersensitivity to PVY is reported in this species. Cyst nematode resistance, both *G. rostochiensis* (Ro_1 and Ro_5) and *G. pallida* (Pa_3) has been discovered in *S. infundibuliforme.* A certain level of drought tolerance was found in it also.

XV. Megistacroloba

Early blight, late blight (non-specific) as well as *Verticillium* resistance was found in *S. toralapanum.* Some resistance to blackleg has been discovered in accessions of *S. boliviense* and *S. toralapanum.* Cyst nematode resistance, both to *G. rostochiensis* and *G. pallida,* is common in species of this series (see *Table 3*). Root knot nematode resistance was found in *S. boliviense.* Insect resistance (colorado beetle and leafhopper) has been reported in *S. boliviense* and *S. megistacrolobum.* Finally the series *Megistacroloba* is well-known for its frost tolerance at least so far as *S. megistacrolobum* is concerned.

XVIIIa. Tuberosa (wild)

This is the most important group of wild species in Bolivia with over 20 representatives. A high degree of non-specific late blight resistance has been found in accessions of *S. berthaultii* and *S. microdontum.*

Tab. 3 Bolivian species of the series *Megistacroloba* and *Tuberosa* with resistance to cyst nematodes and maintained in the "German-Netherlands Potato Collection" at Braunschweig-Völkenrode

Species	Pathotype	2n
S. boliviense	Ro_1	24
S. megistacrolobum	Ro_1, Ro_5, Pa_1, Pa_2, Pa_3	24
S. toralapanum	Pa_3	24
S. alandiae	Pa_3	24?
S. berthaultii	Ro_1, Ro_5, Pa_3	24
S. brevicaule	Ro_1, Ro_5, Pa_3	24
S. gandarillasii	Pa_2, Pa_3	24
S. gourlayi	Ro_5, Pa_1, Pa_2, Pa_3	24, 48
S. leptophyes	Ro_2, Ro_5, Pa_1, Pa_2, Pa_3	24
S. oplocense	Ro_5, Pa_2, Pa_3	24, 48, 72
S. sparsipilum	Ro_1, Ro_5, Pa_2, Pa_3	24
S. × *sucrense*	Ro_1, Ro_2, Ro_5, Pa_1, Pa_2, Pa_3	48
S. tuberosum ssp. *andigena*	Ro_1, Ro_3, Pa_2, Pa_3	48

Wart resistance against different pathotypes has been discovered in different species including *S. berthaultii* (R_1, R_2 and R_6), *S. brevicaule* (R_1), *S. gourlayi* (R_1), *S. leptophyes* (R_1 and R_6), *S. microdontum* (R_1 and R_6), *S. sparsipilum* (R_1 and R_2) and *S.* × *sucrense* (R_1, R_2 and R_6). A certain degree of *Fusarium* resistance was found in *S. gourlayi* and *S. sparsipilum*. Common scab and powdery scab resistances have been reported in accessions of *S. microdontum* ssp. *gigantophyllum* the less common subspecies of *S. microdontum* in Bolivia. A certain degree of blackleg resistance is claimed in accessions of *S. berthaultii, S. gourlayi, S. microdontum* and *S. sparsipilum. Pseudomonas* resistance occurs in *S. sparsipilum.*

As can be seen from *Table 3* there are several species with cyst nematode resistance in series *Tuberosa,* which is undoubtedly the most important source of cyst nematode resistance. The typical foliar hairs of *S. berthaultii* are resistant to mites, thrips and aphids (*Myzus persicae*). This may result in a reduction of susceptibility to insect transmitted virus diseases. *S. microdontum* is an important source of virus resistance (e.g. necrotic response to PVA, PVX and PVY, probably immunity of PVY). PVM resistance is reported in accessions of *S. gourlayi* whereas genes for PLRV are present in *S. canasense* and *S. microdontum.*

Some species, many of which have their main geographical distribution at lower altitudes in dry and/or warm regions possess certain levels of drought-tolerance. They include:

S. gandarillasii, S. gourlayi, S. leptophyes, S. sparsipilum and *S. vidaurrei.*

Not much is known about the biochemical properties of the wild species in Series *Tuberosa.* However, the use of cyst-nematode resistant *S. vernei* from Argentina resulted in a heterosis effect for starch content in the newly bred varieties. High protein content is found in *S. sparsipilum.*

XVIIIb. Tuberosa (cultivated)

As so many varieties of the different cultivated species exist, particularly from *S. tuberosum* ssp. *andigena,* it would go beyond the scope of this publication to list all the properties of these important species. Useful biotic, physiological and biochemical properties can be found in this group of species. Wart, cyst nematode and virus resistance found in *S. tuberosum* ssp. *andigena* accessions have been utilized in potato breeding. Resistance to *Pseudomonas* was discovered in *S. phureja.* Several species such as *S. ajanhuiri, S. juzepczukii, S. curtilobum, S. phureja* and *S. stenotomum* have high levels of frost resistance. Certain forms of *S. phureja* and *S. tuberosum* ssp. *andigena* have shown protein contents above 4 %.

Zusammenfassung

Kartoffelsammelexpedition nach Bolivien und die Bedeutung des bolivianischen Genmaterials für die Pflanzenzüchtung

Im Jahre 1980 wurde eine umfangreiche Sammelreise in Bolivien organisiert, um die in diesem Ursprungsland knollentragender *Solanum*-Arten vorkommenden, bisher jedoch vernachlässigten genetischen Ressourcen zu erfassen. Drei Gruppen mit Wissenschaftlern aus Südamerika und Europa sammelten intensiv Primitivformen und Wildarten in allen geographischen Verbreitungsgebieten des Landes.

Insgesamt wurden 371 Samenmuster von Wildarten und 95 von Primitivformen, ferner 58 Knollenproben, 54 Funde lebender Pflanzen (ohne Knollen) sowie etliches Herbarmaterial eingebracht.

In diesem Material konnten vier neue Spezies und eine neue Subspezies, die bisher nicht bekannt waren, beschrieben werden. Es sind dies: *Solanum circaeifolium* ssp. *quimense* (der Serie VII zugehörig), *S. soestii* (Ser. VII), *S. avilesii* (Ser. XVIIIa), *S. neocardenasii* (Ser. XVIIIa) und *S. okadae* (Ser. XVIIIa).

Anhand der Sammelmuster wird die Taxonomie der bolivianischen *Solanum*-Spezies kurz dargestellt; außerdem wird deren Bedeutung für die Kartoffelzüchtung diskutiert.

References

Anonymous, 1979/1980: CIP Annual Report. Lima, Peru: The International Potato Center (CIP).

COCKERHAM, G., 1956: Potatoes. Ann. Rep. 1956, Scottish Plant Breeding Station, 11—16. Pentlandfield.

ELLENBY, C., 1952: Resistance to the Potato Root Eelworm, *Heterodera rostochiensis* Wollenweber. Nature 170, 1016.

ESTRADA, N., 1977: Breeding frost-resistant potatoes for the tropical highlands. Report of the Planning Conference — Utilization of the Genetic Resources of the Potato II, 51—64. Lima, Peru: The International Potato Centre (CIP).

GIBSON, R. W., 1979: The geographical distribution, inheritance and pest-resisting properties of sticky-tipped foliar hairs on potato species. Potato Res. 22, 223—236.

GLENDINNING, D. R., 1975: Neo-Tuberosum: New potato breeding material 1. The origin, composition and development of the Tuberosum and Neo-Tuberosum gene pools. Potato Res. 18, 256—261.

HAWKES, J. G., 1958: Significance of wild species and primitive forms for potato breeding. Euphytica 7, 257—270.

— —, and J. P. HJERTING, 1969: The potatoes of Argentina, Brazil, Paraguay and Uruguay. A biosystematic study. Ann. of Botany Memoir No. 3 London: Oxford University Press.

HERMSEN, J. G. Th., and J. VERDENIUS, 1971: Wageningen Potato Collection (WAC). Inventory of Seed Stocks, 1—28. Wageningen.

HUIJSMAN, C. A., and H. LAMBERTS, 1972: Breeding for resistance to the potato cykt-nematode in the Netherlands. In: Prospects for the potato in the developing world, 161—171. Lima, Peru: The International Potato Center (CIP).

PLAISTED, R. L., 1972: Utilization of germplasm in breeding programs — Use of cultivated tetraploids. In: Prospects for the potato in the developing world, 90—99. Lima, Peru: The International Potato Center (CIP).

ROSS, H., 1979: Wild species and primitive cultivars as ancestors of potato varieties. Proc.: Conf. Broadening the Genetic Base of Crops, 1978, Wageningen, 237—245. Pudoc, Wageningen.

— —, und C. A. HUIJSMAN, 1969: Über die Resistenz von *Solanum* (Tuberarium)-Arten gegen europäische Rassen des Kartoffelnematoden (*Heterodera rostochiensis* Woll.) Theor. Appl. Genet. 39, 113—122.

ROSS, R. W., and P. R. ROWE, 1969: Inventory of Tuber-Bearing Solanum Species, Bulletin 533, 1—66, Wisconsin Agric. Exp. Sta. (revised).

ROTHACKER, D., 1961: Die wilden und kultivierten mittel- und südamerikanischen Kartoffelspezies. In: SCHICK, R., und M. KLINKOWSKI (Hrsg.), Die Kartoffel, Vol. I, 353—558. Berlin: Deutscher Landwirtschaftsverlag.

— —, 1968: Sortiment wilder und kultivierter Kartoffelspezies, Teil 2, Untersuchungsergebnisse, 1—233. Groß-Lüsewitz: Inst. für Pflanzenzüchtung.

ROWE, P. R., 1969: Nature, distribution and use of diversity of tuber-bearing *Solanum* species. Econ. Bot. 23, 330—338.

SOEST, VAN L. J. M., 1981: Progress of the German-Netherlands Potato Department of the Gene Bank in the FAL. Report of the Planning-Conference Exploration, Taxonomy and Maintenance of Potato Germplasm III, 165—177. Lima, Peru: The International Potato Center (CIP).

— —, and L. SEIDEWITZ, 1981: Evaluation Data on Tuber-Bearing Solanum Species, 1—165. Braunschweig-Völkenrode: Inst. f. Pflanzenbau und Pflanzenzüchtung der FAL. — Wageningen: Stichting voor Plantenveredeling (SVP).

TOXOPEUS, H. J., and C. A. HUIJSMAN, 1952: Genotypical background of resistance to *Heterodera rostochiensis* in *Solanum tuberosum* var. *andigenum*. Nature 170, 1016.

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