Journal of Agriculture and Rural Development in the Tropics and Subtropics

Supplement 92

Agrobiodiversity and Genetic Erosion

Contributions in Honor of Prof. Dr. Karl Hammer

Andreas Buerkert and Jens Gebauer (Editors)

Publisher of the supplement
German Institute for Tropical and Subtropical Agriculture (DITSL GmbH), Witzenhausen
Association for Sustainable Development (GNE mbH), Witzenhausen
Institute for Tropical Agriculture e. V., Leipzig
University of Kassel, Faculty of Organic Agricultural Sciences, Witzenhausen
Alumni-Association Witzenhausen, e. V., Witzenhausen

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To be quoted as
Andreas Buerkert and Jens Gebauer (Editors), 2009:
Agrobiodiversity and Genetic Erosion, Contributions in Honor of Prof. Dr. Karl Hammer,
Supplement No. 92 to the Journal of Agriculture and Rural Development in the Tropics and Subtropics, kassel university press GmbH

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationabibliografie; detailed bibliographic data is available in the Internet at http://dnb.d-nb.de

Publishing House
2009, kassel university press
www.upress.uni-kassel.de

ISSN: 1613 – 8422
ISBN print: 978-3-89958-680-0
ISBN online: 978-3-89958-681-7
URN: urn:nbn:de:0002-6819

Cover layout
Jochen Roth, Kassel

Printed by
Unidruckerei der Universität Kassel

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PREFACE

Prof. Dr. Karl Hammer (born in Leipzig on 17 February 1944) is well known in many parts of the world as a leading scientist in agrobiodiversity and plant genetic resources. After his vocational training on a farm in Auterwitz and his study of agricultural science at the University of Leipzig he joined in 1968 the Institut für Kulturpflanzenforschung der Akademie der Wissenschaften der DDR in Gatersleben. In 1974 he earned his Ph.D. in agricultural science from the Martin-Luther-Universität Halle-Wittenberg. At this time his research focused on the pollination ecology of barley and was supervised by Dr. F. Scholz. Six years later, mentored by Prof. H. Stubbe, Karl Hammer finished his habilitation in the new field of plant genetic resources. After the reorganization of the Institut für Pflanzengenetik und Kulturpflanzenforschung in 1992, Karl Hammer became the new Director of the Gatersleben Genebank and was appointed honorary professor at the Georg-August-Universität Göttingen. In 1998 he became the first Professor of Agrobiodiversity and the Director of the Tropical Greenhouse at the University of Kassel where he enthusiastically worked until his formal retirement in 2009.

Karl Hammer's scientific work covers a wide range of research in plant genetic resources, ranging from ecology and taxonomy to plant domestication, evolution and genetic erosion, conservation and utilization of plant genetic resources, including underutilized and neglected species such as wild fruit trees. In more than 70 expeditions to countries such as Cuba, Eastern Europe, Italy, Iran, Libya, Oman and Korea he contributed to the scientific knowledge about the diversity of cultivated plants. His research results are summarized in more than 500 scientific journal articles and 38 books and book chapters. He has also been a main author of the "Mansfeld's Encyclopedia of Agricultural and Horticultural Crops" which describes all agricultural and horticultural plants, grown throughout the world presently or in the past. Furthermore, he is editor-in-chief of the Journal of Genetic Resources and Crop Evolution and editorial board member of other international journals such as Euphytica, Plant Systematics and Evolution.

Over the years for many of us Karl Hammer has not only been a reliable colleague and an important advisor in the field of agrobiodiversity and beyond but also a well respected, senior friend. During his time as a Professor of Agrobiodiversity he used his encyclopedic knowledge about plants to inspire and vigorously support young scientists from all over the world to publish their research findings in international journal articles. His extensive knowledge of genetic resources and crop evolution contributed substantially to the teaching and research activities of the Faculty of Organic Agriculture at the University of Kassel. The editors would like to use this opportunity to thank Karl Hammer for sharing his knowledge and giving numerous inputs into their own work.

The wide range of research activities but also the humorous character of Karl Hammer is well reflected by the contributions in this special issue of the Journal of Agriculture and Rural Development in the Tropics and Subtropics. The scientific editors wish to thank all authors for their timely submission of typescripts and Hans Hemann for his reliability as the technical editor of the journal.

Witzenhausen, April 2009

Andreas Bürkert

Jens Gebauer

PLANT GENETIC RESOURCES ACTIVITIES OF KARL HAMMER IN CUBA: BRILLIANT SCIENTIST, EXIGENT MASTER AND FAITHFUL FRIEND

Miguel A. Esquivel Pérez

Abstract

During winter of 1983 Karl Hammer, from the Genebank of the Zentralinstitut für Genetik und Kulturpflanzenforschung, Gatersleben, visited the Instituto de Investigaciones Fundamentales en Agricultura Tropical "Alejandro de Humboldt", INIFAT, Cuba for the first time. His first visit occurred within the cooperation between the former German Democratic Republic and Cuba, with the main objective to advice the creation of the National Center for Genetic Resources in Cuba, and to organize on-service training of the Cuban staff. With this cooperation, and particularly due to the personal effort of Karl Hammer, a new generation of plant genetic resources specialists arose in Cuba, combining the experiences of the rich Cuban school of Economic Botany, and the famous German school of taxonomy in cultivated plants. From 1996 to 1994 eight joint collecting missions were carried out in Cuba with participants both from INIFAT and IPK, a total of 1450 accessions were collected, sending many of them as duplicates to the IPK Genebank. Results of the collecting missions and ethnobotanical studies on Cuban cultivated plants yielded more than 50 publications in journals, book reviews and bock chapters. Some other results remained unpublished and are briefly mentioned here.

Key words:
Plant genetic resources, Cuba, Gatersleben

Introduction

To properly understand and assess the value of the results of joint research on plant genetic resources (PGR) activities of Karl Hammer with his colleagues in Cuba it is necessary to provide a brief historical background.

Economic botany had a long tradition in Cuba, however PGR and genebanking activities as properly known did not began in Cuba until the last quarter of the past century, mainly within the frame of the cooperation with the former Soviet Socialist Republic Union and the German Democratic Republic (Esquivel and Leiva, 1992).

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From the XVI to the XIX century the European influence promoted the exchange of cultivated plants between Cuba and the Old Continent. The expeditions carried out by prominent scientists such as Martín Sessé (1795), Baltazar Boldó (1796-1797) and Alexander von Humboldt (1800), showed the first impressions of the rich Cuban Flora and its economic potential. The early establishment of several institutions mainly devoted to the exchange of cultivated plants such as the Jardín Botánico de la Habana (1817), the creation of the Professorship of Agricultural Botany (1824) and the Escuela de Agronomía (1831), increased the awareness of the economic flora of Cuba.

The first half of the XX century was marked by strong Northamerican political and economic influence in Cuba, which had also an impact on the development of agricultural sciences. Sugarcane was already the main industry in Cuba, and E.F. Atkins created the Atkins Garden and Research Laboratory at Soledad, Cienfuegos (1901). A decisive step was the aperture of the Estación Experimental Agronómica de Santiago de las Vegas, EEA (1904), that was directed by outstanding scientists such as F.S Earle, Mario Calvino, G.M. Fortún and Juan Tomas Roig.

Sugarcane, tobacco and coffee continued being among the most important economic crops of the country. New experimental research stations for such crops were created such as Sugarcane Experimental Station in Baraguá, Camagüey (1924), Estación Experimental del Tabaco in San Juan y Martínez, Pinar del Rio (1937), Estación Experimental de Café in Palma Soriano, Oriente (1939) and Estación Experimental de la Caña in Jovellanos, Matanzas (1946).

One of the most significant milestone in the history of PGR in Cuba, were the visits of S.M. Bukasov and N.I. Vavilov during this period. In 1924 the world famous scientist N.I. Vavilov was appointed as Director of the Institute for Applied Botany in Leningrad. He maintained the idea that the PGR of Latin America were still unknown at that moment, least could make a great contribution to plant breeding. Therefore he decided to organize an expedition to Latin America that was carried out between 1925-1926, and was integrated by Y.N. Voronov, S.M. Bukasov, G.G. Bossé, S.V. Iusepchuk, B.P. Zhivago, I.M. Freiderberg and L. Kniaziev.

Bukasov arrived to Cuba on September 1925, spent some days in Havana and continued to join the rest of the group in Mexico. On March 1926 the whole group arrived to Havana, and visited agricultural areas in Havana and Matanzas provinces, as well as the EEA, the Botanic Garden of Havana and other institutions. The impressions of this visit later appeared in his famous book “The cultivated plants of Mexico, Guatemala and Colombia” published in Leningrad in 1930. Among his impressions was that

Cuba, an agricultural country had 10% of its area covered by cultivated plants, but its agriculture, as well as its population was foreign, due to main crops such as sugarcane (50% of crop land), tobacco, bananas, grapefruit and pineapples that were introduced (Bukasov, 1930).

On October 1932 Vavilov himself made a short four days visit to Cuba, arriving from Miami in a hydroplane that covered the route Miami, Havana, Cienfuegos and back. In Havana he visited Dr. Joseph Sylvestre Sauget, known as Brother León, from Colegio La Salle, and Dr. Juan Tomás Roig y Mesa in the EEA Santiago de las Vegas. He also made a short trip to Atkins Botanical Garden in Cienfuegos. The impressions of Vavilov about Cuba appeared in his book "Five Continents" that he prepared in 1939 and was published postmortem in 1962. In this book he dedicated a chapter to Cuba and Puerto Rico named *"The Island of Cuba and its Tragedy"* that sturdily reflected the hard situation of the country. Unfortunately the chapter remains unconcluded and only a script remains that compressed the following sections*: "Indigent professors. Jesuits. Havana cigars. The land of agaves. History of sugarcane. Gardens of introduced plants. Cienfuegos (San Fuegos in the text). The island of Puerto Rico. Introduction nurseries. A philosophy of the island. Flying back to Miami"* (Vavilov, 1997).

The Cuban historian Francisco Dias Barreiro cited a brief report made by Vavilov about his visit to Cuba in 1932 (Díaz Barreiro, 1977), where he called Cuba *"the land of sugarcane and tobacco"* and wrote: *"I have not seen anything original in Cuba. There were varieties from EEUU. There were plants imported from the northern coast of South America. Large sown fields and plantations of tropical crops: sugarcane, henequen, etc., were surprising."*

The ideas expressed by Bukasov and Vavilov about the poverty of Cuban PGR, based on their short and limited visits, probably provoked the disinterest of further scholars and researchers on the exploration and study of Cuban cultivated plants, being concentrated subsequent expeditions and search of in the wild flora.

After the Revolution in 1959, some other agronomic research institutions were created for specific crops, among them the Centro de Mejoramiento de Semillas Agámicas (CEMSA) in Santo Domingo, Santa Clara (1967) for root, tubers and starchy plants; and Estación de Plantas Medicinales "Juan Tomás Roig" in Güira de Melena, Habana (1973) for medicinal plants.

In 1967/68 the first Alexander von Humboldt Expedition was carried out in Cuba, with participation of East German and Cuban specialists (Rieth, 1969). Even if it mainly focused on wild plants, it revealed ones more the economic potential of PGR in Cuba.

At the end of the 70s the Experimental Station of Santiago de las Vegas reinitiated the cooperation with N.I. Vavilov Plant Industry Institute (VIR) in Leningrad. The Experimental Plot "Amistad" was created to trial in Cuba genetic material imported from the former Soviet country.

With the celebration of 70^{th} Anniversary of EEA in 1974 it was renamed Instituto de Investigaciones Fundamentales en Agricultura Tropical "Alejandro de Humboldt" (INIFAT), being signed an Intergovernmental Agreement between German Democratic Republic and Cuba, broadening the cooperation between Cuban and East German institutions.

Several Cuban scientists visited for the first time the Zentralinstitut für Genetik und Kulturpflanzenforschung (ZIGuK), Gatersleben. Among them were Alfredo Travieso, Alberto Alfonso and Raúl Cristóbal, who initiated joint research in the fields of plant physiology, tissue culture and biophysics respectively.

The soviet specialist Vladimir Kudielich, visited Cuba in the late 70s, with his support the first working methodology proposal for a Genebank was written and the Genebank was created in 1980 within Department of Genetics and Plant Breeding.

During winter of 1983 Karl Hammer, from the Genebank of the Zentralinstitut für Genetik und Kulturpflanzenforschung, Gatersleben, visited the Instituto de Investigaciones Fundamentales en Agricultura Tropical "Alejandro de Humboldt", INIFAT, Cuba for the first time. This visit occurred within the cooperation between the former German Democratic Republic and Cuba, with the main objective to advice the creation of the National Center for Genetic Resources in Cuba (NCGR), and to organize on-service training of the Cuban staff. Close to this visit, Dr. Rafael Martínez Viera, Head of the Genebank at the moment, and Architect Mirza Toledo, travelled to Gatersleben to gain elements for the design of the facilities of the NCGR, and coordinate further training activities for the young Cuban specialists. The author had the privilege to be included as one of the first two students that travelled to Gatersleben the next year.

Brilliant Scientist

The scientific activities of Karl Hammer in Cuba covered several areas, being the most significant the exploration and collection of Cuban PGR, and the ethnobotanical studies about the cultivated plants in Cuba.

Exploring and collecting PGR in Cuba. Collecting missions to Cuba. Diversity in collected materials.

The exploration and collection of PGR in Cuba were one of the most relevant issues in the cooperation between ZIGuK and INIFAT. From the very beginning Karl Hammer believed that the flora of cultivated plants in Cuba was still understudied. With the exception of some botanists such as Manuel Gomez de la Maza, Juan Tomás Roig and Julian Acuña, most of the other botanists were fascinated by the wild flora of Cuba and therefore concentrated their studies on wild species.

After preliminary discussions we elaborated a joint guiding question for our work: If the diversity of cultivated plants is the result of the man-made selection and if Cuba has a very diverse cultural background, very variable landscapes and a very rich wild Flora with more than 6000 species being more than half endemics, why should the cultivated plants should not be diverse too?

To answer this question an exploration and collection program was initiated, that tried to cover the areas of most potential diversity for cultivated plants and their wild relatives. From February 1986 to March 1993 eight joint exploration and collection missions were carried out in which Karl Hammer participated (Esquivel et al., 1987, 1988, 1989b, 1990c, 1994b,f; Hammer and Esquivel, 1991a; Hammer et al., 1991a).

The methodology we used in our expeditions followed more closely that proposed by the famous Mexican master Efrain Hernández Xolocotsi (Hernández, 1971) for ethnobotanical explorations, than the one published by IBPGR for germplasm collection (Hawkes, 1980). The preparation before the expeditions forced us to study the history of different localities, ecosystems existing in the areas, as well as other details that could help us to spots potentially rich in PGR. During the expeditions we strongly relied on the vast knowledge and charisma of local partners, which as our friends and cooperators Bartolomé Rodriguez "Bartolo" in Holguín, Haroldo Uranga in Habana, and "Pindo" Pantoja in Isle of Youth were key persons to the success of our missions.

With the exception of the provinces Ciego de Avila and Camagüey, the rest 12 provinces of Cuba as well as the Isle of Youth were covered (Table 1). A total of 1450 accessions were collected belonging to more than 200 crop species and their wild relatives. Duplicates of this material was sent to Gatersleben for storage and or taxonomic identification.

Other expeditions were carried out by INIFAT in cooperation with Cuban institutions trying to fill some gaps, where the same methodology developed with ZIGuK was used (Esquivel et al., 1986, 1990b, 1991).

Table 1. Summary of the ZIGuk/IPK-INIFAT plant genetic resources exploring and collecting missions in Cuba (1986-1993).

Mission	Dates	Area	Accessions	References
1st	February 1986	Holguin-Las Tunas	249	Esquivel et al., 1987
2nd	December 1986	Holguín, Santiago de Cuba, Guantánamo	202	Esquivel et al., 1988
3rd	March 1988	Pinar del Río, Habana, Isla de la Juventud	284	Esquivel et al., 1989b
4th	March – April 1989	Santiago de Cuba, Guantánamo	236	Esquivel et al., 1990c
5th	February – March 1990	Granma, Holguín, Santiago de Cuba	170	Hammer et al., 1991a
6th	December 1990	Habana	69	Hammer and Esquivel, 1991a
7th	February – March 1992	Pinar del Río, Habana, Matanzas, Cienfuegos, Villa Clara, Sancti Spiritus	144	Esquivel et al., 1994f
8th	March 1993	Matanzas, Cienfuegos, Villa Clara, Sancti Spiritus	214	Esquivel et al., 1994b
Total			1450	

Agricultural areas traditionally important such as the Southern part of Habana provinces, or the zone of Velazco in Holguín, popularly known as "the granary of Cuba", were not rich in PGR, since their production was based on a few highly productive cultivars. However areas of traditional agriculture with both diverse natural and cultural background were as expected very rich in plants and genetic diversity. In some areas such as the mountainous region of the South of Guantánamo, great ecological variations could be found in relatively small areas, from a desert near the coast, to the tropical cloud forest in the near mountains.

Places such as el Cerro de Yaguajay in Holguín, ancient place of the Taino aborigine culture; la Caridad de los Indios in Guantánamo, where still descendants of the Cuba aborigines can be found; or la Loma del Grillo in Habana, where the last Yucatecan aborigine descendants living, were particularly very rich in traditional American crops such as maize, beans and peppers. Other areas in Sierra del Rosario, Pinar del Rio, where are remains of "palenques", villages in the forests where escaped slaves used to live, several old landraces of roots, tubers or fruits were found which had escaped from cultivation. Localities where ethnic minorities live, most likely such as the Japanese farmers in Júcaro and Ciro Redondo, Isle of Youth, gave us the possibilities to find crops such as soybeans to prepare the traditional cheese "tofu". In other areas with intensive agricultural production such as the Valle del Caujerí in Guantánamo, still crops as chickpeas or the Big Lima types of lima bean (*Phaseolus lunatus*) can be found, which were traditionally exported to US by the Guantánamo Navy Base.

The "conucos", traditional homegardens, proved to be a very important agroecosystem for the domestication and evolution of plant genetic resources (Esquivel and Hammer, 1988, 1992c,d, 1994b). We found cultivated plants and wild relatives coexisting, as well as interesting examples of incipient domestication or plants that had escaped from cultivation.

An early unpublished working document showed that there were 144 cultivated taxa of vegetables and spices in Cuba (Esquivel, et al., s.a.). The tomato *Lycopersicon esculentum*, was one of the crops most often collected. Landraces such as placero and the weedy *L. esculentum* var. *cerasiforme* known as tomate cimarrón, showed also several evidence of introgression among them. The ají (*Capsicum frutescens*) was also a very variable crop, with several landraces as aji guaguao, aji cachucha, aji calilla and arroz con pollo. In traditional agricultural systems, instead of onion, the so called cebolla multiplicadora or cebollin (*Allium cepa* var. *aggregatum*) is widely used. Its small bulbils have a great ability for storage, and field trials demonstrated resistance to *Alternaria* sp. as well as the possibility to set flower and seed under Cuban conditions. Other *Allium* species known as cebollinos showed a rich variation, such as on Isle of Youth where species as A. *fistulosum*, *A. tuberosum*, *A. chinense*, *A. macrostemum* and *A. porrum* were found. The *Allium* group proved to be one of the more intriguing ones, with some mysterious immigrants, as we called them, as it was demonstrated in more deep ethnobotanical and biosystematic studies (Esquivel and Hammer, 1992a, 1994a).

Representatives of the *Cucurbitaceae* family also were a very variable and interesting group. Another unpublished document about the genetic resources of the *Cucurbitaceae* family in Cuba, showed that in Cuba this family was represented by 19 genera and 36 species, being the more represented *Cucurbita* (6 species), *Cucumis* (4) and *Anguria, Cayaponia* and *Momordica* with 3 species each (Esquivel et al., s.a). Some 19 species are cultivated, mainly from the genera *Citrullus, Cucumis* and *Cucurbita*; Some species have escaped from cultivation such as *Citrullus colocynthis, Coccinia grandis* and *Cucurbita foetida*; and 14 are wild from the genera *Anguria, Cayaponia, Cianocissyos, Elatherium, Melotrhia* and *Sicidium*. From the wild species some can be used in plant breeding such as *Citrullus* *colocynthis, Cucumis anguria* or *Cucumis melo* subsp. *agrestris*, while others such as species of the genus *Benincasa, Coccinia, Fevillea, Lagenaria, Luffa, Momordica, Sechium, Sicana* and *Trichosanthes,* remain unknown or under-exploited as new crops. Pumpkins are part of the traditional maize-bean agricultural system typical for Central American aborigines. *Cucurbita moschata* was one of the most variable crops in which we discovered evidence of introgression between typical landraces such as calabaza de pescuezo, cuero de sapo o sello de oro.

Together with vegetables and spices, pulses were the other group of species more widely collected. As mentioned above beans are part of the traditional agricultural system for American aborigines.

A completely unexpected variability was found in the landraces and wild relatives of the Lima bean (*Phaseolus lunatus*). The three cultivar groups for this species Sieva, Potato and Big Lima were found in Cuba, but all possible intermediate forms between them were also found. Detailed morphological and biochemical studies of their phaseolin types evidenced introgressions between all cultivated types. Wild and weedy forms were also discovered in the mountains around Havana and Grupo Guamuhaya, providing strong evidence that this crop has a secondary center of evolution in the Caribbean and particularly in Cuba (Castiñeriras et al., 1994a,b; Esquivel et al., 1990a, 1992b; Lioi et al. 1991).

The common bean (*Phaseolus vulgaris*) expressed a wide variation. While in Western and Central Cuba more variation was found in white, pink, red and mottled types, in Eastern part of Cuba black genotypes were predominant. Usually more dark seeded landraces were considered as more disease resistant, while light seeded ones had a better cooking quality. Several farmer used to sow mixed populations, and according to the climatic conditions of the season, light or dark material predominated, but always ensured a good harvest (Castiñeiras et al., 1991, 1994b; Lioi et al., 1990).

Several *Vigna* species were also cultivated, with variable uses as fodder crops, vegetable and grain crops. The more popular species are cowpea (*V. unguiculata* subsp. *unguiculata*), habichuela china (*V. unguiculata* subsp. *sesquipedalis*), but also frijolito chino (*V. radiata*) and frijol arroz (*V. umbellata*). A total of 14 *Vigna* taxa are cultivated in Cuba, and their wild relatives *V. adenantha*, *V. antillana*, *V. longiflora* and *V. trichocarpa* were also found (Esquivel et al., 1992e; Beyra and Reyes, 2004; Perrino et al., 1991).

Other pulse species had very interesting uses, such as those used as a surrogate for coffee, *Canavalia gladiata* and *Mucuna pruriens* subsp. *deeringiana*. Some interesting species such as the jícama (*Pachyrrizus erosus*) was also found, with its edible seeds and roots, but considered in some areas as repellent to bibijaguas (*Atta insularis*).

Cuba dos not have a tradition for oil crops but some peanuts (*Arachis hypogaea*) and sesame (*Sesamum orientale*) are cultivated. In areas around Havana and central provinces promising materials with potential for plant breeding were collected, mainly derived from US material used in commercial plantations for oil extraction. Sesame is more related to traditional systems (Esquivel et al., 1992a,d, 1994a; Fundora et al., 1993).

Maize was among the crops first seen by the Europeans in Cuba, during the first trip of Columbus. Some specialists considered that these were maize flint types carried by Columbus to the Old World, and the name panizo given by Columbus to identify the new crop, is still used in some places of Southern Spain to identify such flint types. A very interesting study was carried out in Cuba in the 50s by the University of Harvard within the frame of the study of the Latin American races of maize (Hatheway, 1957). A total of seven landraces were identified namely Criollo, Tuzón, Canilla, Argentino, Yellow Pop, White Pop and White Dent. Materials of the first four races were often collected, but with the exception of the race Canilla, called by farmers 'tusita' or 'tusifino', it was difficult to find pure races due to introgression among them as already reported by Hatheway.

Sorghum species were also collected, both grain types, but also primitive cultivars with big open panicles formerly used to make brooms.

As mentioned already, roots, tubers and starchy crops were not the main objective of our exploration and collection missions. However, some materials were collected and transferred to their corresponding genebanks in Cuba. The greatest variability was found in sweet potato (*Ipomoea batatas*), confirming reports by Roig and Fortún (1916) about the great variability of this crop in Cuba, based on the study of more than 200 collected materials that showed the existence of nearly 500 different.

Citrullus colocynthis was a plant collected growing wild near the coast of South Guantánamo and known by the name coloquíntida. It was reported in Cuba as introduced form the EEA some decades before. The situation was similar for *Phaseolus coccineus* found cultivated in one garden in El Quemado, Sierra de Nipe, withput any reference about its origin in Cuba.

Some landraces such as those collected from grapes (*Vitis vinifera*) in Valle del Caujerí, East Cuba, have their wild relatives parra cimarrona (*Vitis tiliaefolia*) near Pan de Guajaibón in Western Cuba (Esquivel et al., 1994b). Other former cultivated species probably introduced by Europeans in the mountainous zones, were found as relicts in some gardens, such as the mora (*Morus nigra*) collected in Monte Verde, Yateras. Old landraces of cotton were found growing wild, in the same areas that Columbus reported them more than five centuries before. Some wild species are used but not cultivated such as the wild papaya (*Carica prosoposa*) or the guayabita del Pinar (*Psidium guayabita*) the last being used to prepare a local liqueur in Pinar del Rio (Esquivel et al., 1994d).

Ethnobotanical Studies on Cultivated Plants in Cuba.

It was not only valuable genetic material that was collected during expeditions, but also information about their history, evolution and use. Since the very beginning Karl Hammer introduced us to the idea of tring to understand the relationship between humans and plants, as one of the principles of ethnobotanical exploration. In every expedition we tried to focus our interest on a particular group or use of plants, according to the area that would be explored.

One of the first groups were hedge plants. The history of plants used for living fences, is very much associated to the evolution of traditional farming systems. The Spanish word 'seto' to designate hedge, comes from the Latin *septus*, meaning division. Aborigine agricultural systems did not have divisions of their fields, because they belonged to the community and they did not have domestic animal that could affect crops. Living fences were introduced by the Europeans in the traditional 'conucos'. A checklist was compiled with 51 species used as hedge plants in Cuba, belonging to 33 genera and 13 families, among them legumes with 12 species are widely used. Most of the plants with this specific use have spines (Hammer, 1988) for the cactus and succulents used as living fences in Cuba.

Magic and medicinal plants may be the plant group that best represent the evolutionary relationship between plant and man. The author was engaged in a technical revision of *El Monte*, a marvelous compilation about the uses of plants in Afro-Cuban religions. African influence has been one of the strongest in Cuban culture, since more than one million slaves from West Africa were introduced in Cuba to work mainly in the sugarcane industry. They mixed the catholic religion with their native religions from Africa, creating the so called syncretic religions, were plants and animals were one of the main ways to promote communication between man and their gods. Among the main religions are Ocha Rule or Santería, related to Yoruba culture, Nigeria; Palo Monte Rule or Mayombe, from Bantú culture, Congo; Arará Rule, from Dahomey, Senegal; and Secret Society Abakuá, Efik culture. A total of 975 taxa were identified to be used by these afrocuban religions, that were known by 960 folk names, 866 yoruba names and 474 congo names. A total of 409 of these taxa (42%) were plants originated from America then introduced to Africa as maize or cassava; 273 taxa (28%) were African plants introduced to America (Esquivel et al., 1992c, 1995).

Also immigrants from East Asia had their influence on Cuban agriculture. Upon exploring and collecting PGR in Cuba a deeper study was dedicated to this topic. By 1861 nearly 60% of the Cuban population was either black or mulatto, therefore the Royal Board of Development, Agriculture and Trade tried to boost the number of non-African imigrants to Cuba. In only 20 years from 1853 to 1873 more than 130 000 Chinese arrived to Cuba. Japanese immigration occurred decades later. From 1920 to 1930 Japanese farmers arrived to Cuba seeking jobs mainly in the sugarcane industry of Camagüey. Some of them later moved to Isle of Youth to be engaged in vegetable production with northamerican farmers for US export. Our study revealed that 44 crop plants from 32 genera and 22 families were of an East Asiatic origin, many of them were directly introduced by East Asian immigrants, such as demonstrated by toponymy evidences (Hammer and Esquivel, 1990, 1992).

A total of 10 *Allium* taxa in Cuba were identified, demonstrating to be an interested example of ethnobotanical classification according to chronological arrival by different cultural groups. Early introductions by Europeans included *A. cepa* var. *aggregatum*, *A. sativum* var. *sativum* and *A. fistulosum*. Introductions from East Asia comprised taxa such as *A. tuberosum*, *A. sativum* var. *pekinense* and *A. chinense*. *A. cepa* var. *cepa*, *A. porrum* and *A. schoenoprasum* have been relatively recently introduced. An interesting group is formed by what we decided to call “mysterious immigrants” being represented by material collected in Monte Verde, Guantánamo, which was further classified as *A. canadense* after intensive morpho-anatomical research that included SEM investigations on testa epidermis. During the Allium Symposium in Gatersleben 1991, Dale McNeal from Stockton, California and William Stearn from the British Museum, classified this plant material as *A. canadense* var. *canadense* and as var. *fraseri*. This species is known in North America as wild garlic, meadow leek or wild onion and had been used for its edible leaves by native Americans and European settlers. May be European settlers also introduced it on the Antilles, mainly to Santo Domingo and Haiti. After the Haitian Revolution (1791–1804) many French settlers leaved Haiti and installed themselves in coffee plantations in the mountains of the former Cuban Oriente. May be *A. canadense* was one of the species these settlers brought to be cultivated in their gardens. Other material remained was still unidentified but resembled *A. glandulosum* (Esquivel and Hammer, 1992b, 1994a).

Endemic wild relatives of cultivated plants in the Flora of Cuba comprise 807 wild taxa (Rodríguez et al., 1994a). In order to better understand the relationships between cultivated plants and their wild relatives, in the last joint missions between IPK and INIFAT, other research institutions were invited such as the National Botanic Garden (NBG) and the Institute of

Ecology and Systematic (IES), to explore, collect and study the wild relatives of some important cultivated plants. One of the first targets was the genus *Ipomoea* for the potential value of wild relatives in plant breeding. Previous wild *Ipomoea* collection missions carried out by other institutions yielded poor results. A deep study in the herbaria of NBG and IES allowed to identify areas with high potential diversity in wild *Ipomoea* species, which together with other ecological and phonological data allowed tracing more effective collecting routes. A total of 53 accessions were collected. Besides the cultivated potato (*I. batatas*) 50 accessions were collected of the wild relatives *I. acuminata*, *I. alba*, *I. aquatica*, *I. asarifilia*, *I. cairica*, *I. carnea* subsp. *fistulosa*, *I. pes-caprae* subsp. *brasiliensis*, *I. purpurea*, *I. tiliacea*, *I. triloba* and *I. trifida* (Esquivel at al., 1994b). All collected material was planted as a permanent living collection for further study at INIFAT. One of the participants of our mission, Pedro Herrera from IES, later prepared a comprehensive manuscript that unfortunately remained unpublished, about the genus *Ipomoea* in Cuba. In his report he provided interesting and detailed information on the 57 species of the genus reported for Cuba, including descriptions, identification keys and ecological data.

One of the results from the joint IPK-INIFAT ethnobotanical studies that had most impact are those related to homegardens. The original idea of this work came from Miguel Holle, former coordinator of the International Board for Plant Genetic Resources for Latin America during his visit to Cuba in the early 80s. Early papers published by Esquivel and Hammer (1988, 1992c, 1992d, 1994b) showed the importance of this agroecosystem as a perspective environment for the evolution and *in situ* conservation of Cuban PGR. After exchanging some preliminary ideas with Toby Hodgkin from IBPGR a first draft project proposal was prepared (Esquivel et al., 1994c). The proposal was submitted to IBPGR and included the creation of a national network of 30 sites for *in situ* conservation of PGR, selected on the basis of ecological and cultural diversity.

It was necessary to organize, store and analyze all the data gathered during the exploration and collection missions, as well as those resulting from the ethnobotanical studies. Karl Hammer and Helmut Knüpffer had experience in compiling checklists of cultivated plants from other countries such as Lybia, Korea and Italy (Hammer, 1990). The first checklists were made by traditional methods, whereas the Italian checklist was automatically generated by a database of the Cultivated Plants of Cuba (DBCPC) (Knüpffer et al., 1990; Knüpffer, 1992). The first checklist was produced (Esquivel et al., 1989a), having two further additions (Hammer et al., 1990; 1991b). These allowed us to compile the Inventory of the Cultivated Plants in Cuba (Esquivel et al., 1992e).

In the summer of 2001, IPK hosted the symposium "The Genus Allium – Taxonomic Problems and Genetic Resources", which also allowed to present the results on the study of the cultivated *Allium* species in Cuba (Esquivel and Hammer, 1992a). Nearly at the end this presumed short stay, Prof Hammer revealed the true intention of this visit, which resulted in one of the greatest surprises I ever got: he managed to get some funds from GTZ to prepare and publish a book about PGR of Cuba. After consulting INIFAT in Havana, I decided to postpone the final step of my PhD thesis preparation, prolonged my stay in Gaterleben and began to draft a script for the book and approach colleagues to cooperate.

After a very intense working year, we finished the first two volumes of the "Green Book" as we further called it with affection. It was entitled "*"Y tienen faxones y fabas muy diversos de los nuestros" Origin, evolution and diversity of Cuban plant genetic resources"*, borrowing the words used by Christopher Columbus in 1492 when he described the beans he found in the northern coast of the actual province of Holguín. The first volume summarized different cultural influences on Cuban agriculture, being the main one aborigine (Esquivel and Hammer, 1992b), European (Hammer et al., 1992a), African (Esquivel et al., 1992c) and East Asian (Hammer and Esquivel, 1992). The second volume resulted in a compilation of the cultivated plants of Cuba (Esquivel et al., 1992e). A third volume appeared in 1994 (Hammer et al., 1994). and included chapters about the utilization of PGR in Cuba (Fundora et al., 1994), the National Database of PGR (Esquivel et al., 1994d) and the *ex situ* preservation of PGR (Rodriguez et al., 1994b).

Some of the studies we initiated led to deeper follow-up studies, such as those related to the nature and landscapes described by Columbus on his trips to Cuba (Esquivel and Casals, 2005, 2006, 2006a); ethnobotanical studies related about Solanaceae (Esquivel and Hammer, 1989, 1991b), medicinal plants (Hammer et al., 1989); fruits and wild relatives (Esquivel et al., 1994e); documentation of PGR (Jiménez et al., 1997); the evaluation and use of PGR (Esquivel et al., 1992a, d,1994a; Estévez et al., 1994; Fundora et al., 1993; Krieghoff et al., 1991).

The results of the joint cooperation between INIFAT and IPK were presented at the meetings of the Genetic Resources Program of former COMECON countries (Esquivel, 1989), and considered as one of the relevant results of the cooperation between Cuba and former GDR (Esquivel and Hammer, 1990, 1991a; Hammer and Esquivel, 1991b).

The Exigent Master

In 1991 the Journal Diversity dedicated an special issue to PGR activities worldwide. A short article was devoted to the cooperation between Cuba and Germany in the field of PGR (Hammer and Esquivel, 1991b). Once asked about the causes that promoted such fruitful program, Karl Hammer responded that those were the combination of Cuban enthusiasm and German discipline. This statement characterizes well the effort made by Karl Hammer in our training and education.

On May 2004 I spent my first three months training period in Gatersleben Genebank. This first stay showed me Karl Hammer's "German discipline", something that I am thankful ot have known for the rest of my life. Appearing the opening day in his office with my suit, necktie and tight new shoes, I never will forget his phrase "How handsome, you look like a *señorito*, let's go to the field!", we subsequently spent the rest of the morning touring experimental plots.

Upon arrival to my room in the guest house, there was a large pile of books at my bedside table, confirming, that Gatersleben was a quite village with no night life, so we had all night to study. Another surprising fact for us was the "mysterious folders" travelling from one desk to another every day. Soon we learned being included into the system, in which hundreds of journals received by the library, before going to their definitive depot at the library had to be check by all staff.

At that time Karl Hammer was already a world-wide recognized specialist in the field of PGR, therefore it was common to see on his desk several books waiting to be reviewed. I noticed that he often borrows some of these amazing books, but the next day in the morning was asked for my opinion about it.

At a time when the Internet did not yet exist, we could access and learn how to use sources of information such as the Mansfeld's library, microfilms collections, the herbarium and the fruit and seed collections.

The first visit to Gatersleben also introduced us to practical genebanking activities such as the seed laboratory and seed preservation.

During our training periods at Gatersleben, Karl Hammer did not only care about our professional formation, but also how to broaden our cultural horizons, accompanying us to unforgettable experiences such as the organ concerts in monasteries near Wernigerode in the Harz mountains; showing us the Bauhaus design school in Dessau; visiting with us historical places in old Berlin; and the Botanical Garden of Leipzig.

The solid professional formation we acquired in Gatersleben under Karl Hammer opened me many doors in my future professional life. Few months after my first visit to Gatersleben, I had also the opportunity to get a two month training course at VIR Leningrad, which also allowed me to meet Academician V. F. Dorofeev.

I must confess that the German discipline was sometimes traumatic for me, but I finished up by appreciating it. I vividly remember the travel back I have to do very early in the morning to plant again some pieces of an endemic cactus I irresponsibly collected at Loma del Fraile in Holguin during a collection mission.

Since the very beginning I was very impressed about the large amount of articles Prof. Hammer had published. One day I asked him about his method to be so productive. He simply answered: “very easy, just write one page per day and at the end of every year you’ll have a 365 pages book. But you have to write every day, and remember that the page you are writing today has to be relat to the page you wrote yesterday and the page you are thinking to write tomorrow”.

The Faithful Friend

A decisive factor to carry out the above mentioned work was the friendly environment that always surrounded our relationships, even during very difficult and stressfull situations, Karl Hammer proved to be a faithful friend.

During my first visit to Gatersleben, he took me at his home to become part of his family, making easier long stays of hard study and work time there. His first wife Sonja was an experienced mother who took care of us during our frequent visits. His daughters Carola and Angelika were the friends that introduced us in the German way of live. After he recovered from Sonja’s regrettable early dead, he was able to rebuild a new family. After 12 years without visiting Gaterleben, we were thankful to visit him again at home with Italian and Japanese colleagues and we met his wife and new little son Karl.

Karl Hammer had the patience to deal with young inexperienced people like me, newcomers to the complex world of PGR, but also with old experienced scientists, coming from a plant breeding background.

During the hard economic situation that Cuba experienced in the early 90s, he never complained about the sometimes difficult and dangerous situation in whick we had to carry out our work. Sometimes sleeping in an small hamaca or on the floor in a children camp as we had to in Chorro de Maita, Holguín, or travelling thousands of kilometers in an uncomfortable Hungarian Aro rural car as during our trip to Punta de Maisi, Guantánamo, or when this car was seized by the military who erroneously took us as US spies during an army exercise near the Guantanamo Military Base.

Karl Hammer always shared with us what he had: from a second hand bicycle to a botanist's magnifying glass; from a box of writing paper, to a scientific calculator; from a bag of detergent to a photographic camera and films; from canned meat to seeds from my garden. Many times he talked about difficult situations during war times in Germany, and the efforts to keep up work and rebuild the institute.

Karl Hammer demonstrated that friendship was stronger that any scientific, political or economic obstracle. Nobody could expect that one day the Berlin Wall would fall, the two German states divided for more than 40 years would merge again, and the cooperation program between the the German Democratic Republic and Cuba would disappear.

Acknowledgements

The present article should be considered as my humble contribution to someone with whom I will be always in debt, not only for the great scientific results he contributed to my country, but for the ethical and human values he forged on all of his Cuban colleagues. As such this paper resumes main activities and results of 25 years cooperation with Karl Hammer in Cuba, in the field of plant genetic resources, showing his values as a brilliant scientist, exigent master and as a faithful friend.

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TAXONOMICAL AND MORPHOLOGICAL ASSESSMENTS OF INFRA-SPECIFIC DIVERSITY IN CULTIVATED FLAX (*LINUM USITATISSIMUM* L.)

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Abstract

Agrobiodiversity research and efficient genebank management need tools for qualitative and quantitative assessments of crop diversity at the infra-specific level. For 2,748 accessions of flax (*Linum usitatissimum* L.) from the collection at Plant Gene Resources of Canada (PGRC) a grouping at the infra-specific level into four convarieties and 26 botanical varieties was conducted. Alternatively, for 2,545 accessions, genetically distinct morphological groups were defined using seven highly heritable morphological characters with 19 distinct character states. Both methods showed concentration towards a few phenotypic groups within the flax collection. Both methods also indicated a reduction of phenotypic diversity over time within 61 North American flax cultivars released during the 20th century. The results of the infra-specific classification showed that the same phenotypic groups dominated the flax accessions held in the German (Leibniz Institut für Pflanzengenetik und Kulturpflanzenforschung, IPK) and the Canadian (PGRC) national seed genebanks. The assessment of functional diversity within large genebank collections remains an urgent task. The methods applied here can be used to survey large germplasm collections or subsets of the flax gene-pool.

Key words:
diversity assessment; germplasm characterisation; genebank management; infraspecific classification; phenotyping; taxonomy

Introduction

Genebanks have the objective to preserve the genetic diversity of a crop species at the infra-specific level. This requires systematically describing and communicating diversity at the different diversity levels (Hammer 2003). Efficient collection management is based on qualitative and quantitative assessments of the phenotypic variation existing in species. The traditional approach is the application of taxonomic principles at the species and infra-specific levels resulting in formal hierarchical classifications (Hanelt 1988).

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Linnaeus (1753) distinguished four types of *Linum usitatissimum*. Large seeded flax, winter hardy flax and flax with spontaneously opening capsules were described by early researchers of cultivated plant diversity and named as distinct taxa (Elladi 1940; Kulpa and Danert 1962; Diederichsen and Richards 2003). Alefeld (1866) described eleven botanical varieties of cultivated flax. Based on the characteristics seed colour, petal colour, anther colour, filament colour, style colour and seed size, Howard (1924) suggested a grouping of Indian flax into 26 botanical varieties. Elladi (1940) refined and expanded the classification to 119 botanical varieties by studying the world collection of flax at the All-Union Institute of Plant Industry at Leningrad (now: N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry, VIR, St. Petersburg). Kulpa and Danert (1962) studied the world collection of flax at the Institut für Kulturpflanzenforschung at Gatersleben, Germany (now: Leibniz Institut für Pflanzengenetik und Kulturpflanzenforschung, IPK) and proposed 28 botanical varieties of cultivated flax. The most recent formal classification of cultivated flax was proposed by Černomorskaja and Stankevič (1987); it limited the formal infra-specific distinctions to five subspecies (Diederichsen and Richards 2003). While all these classifications, and in particular those proposing many infra-specific taxa, are excellent tools for describing and documenting the diversity of cultivated flax, that is, the qualitative assessment of genetic diversity, they have rarely been used for quantitatively assessing the genetic diversity in genebank collections or selected gene-pools. Instead, molecular methods have recently been used for assessing redundancy in the flax collection at Plant Gene Resources of Canada (PGRC) (Fu 2006). The morphological characters used in taxonomic classifications are easy to observe, inexpensive to describe and it is possible to screen and categorise large numbers of accessions, which are great advantages when managing germplasm collections (FAO 1996). For decades the need for phenotypic germplasm characterisation in genebanks has been emphasised (Lehmann und Mansfeld 1957, Engels and Visser 2003).

In this study the formal infra-specific classification suggested by Kulpa and Danert (1962) was applied to the flax world collection preserved by PGRC. Simultaneously, a selected set of highly heritable morphological characters was used to assess the diversity in the PGRC collection by defining genetically distinct morphological groups. This method has previously been applied to survey the large oat (*Avena sativa* L.) collection of PGRC (Diederichsen 2008). Both methods were also applied to assess the diversity trends within 61 North American flax cultivars released during the 20th century. This study also demonstrated how the infra-specific classification can be used to compare the composition of large genebank collections, because the infra-specific classification used had earlier been applied to the flax collection at the IPK genebank.

Materials and Methods

Plant Material

This investigation was based on 2,748 accessions from the PGRC flax collection, which originated from 69 countries covering all areas with present or historic flax production. A total of 61 North American flax cultivars consisting of eight fibre flax cultivars and 53 linseed cultivars released during the 20th century were also included in the studied germplasm (Table 1). For the IPK collection, the passport data listing the infra-specific determination of 1606 accessions was supplied by the database manager (H. Knüpffer, IPK, personal communication), it is also available from the Internet (IPK 2008).

Field Plots and Morphological Descriptors

Descriptor data were collected during field regeneration and after cleaning harvested seed. Regeneration and characterisation plots were spring planted on a loamy, dark chernozemic soil at Saskatoon (52° 10' N, 106° 41' W, altitude 501 m above sea level), Saskatchewan, Canada, during the years 1998-2004. For sowing, a random seed sample of 2 g from each accession was used and placed in single rows of 3 m length without replication. A comprehensive set of 27 descriptors using qualitative morphological characteristics indicating genetic differences was applied according to the list proposed by Diederichsen and Richards (2003). The characters used by Kulpa and Danert (1962) for their infra-specific grouping were included in the descriptor list (plant height, stem branching, 1000 seed weight, seed colour, capsule dehiscence, petal colour, petal margins overlap, flower shape, petal width/length ratio). For all 2748 accessions, the infra-specific categories proposed by Kulpa and Danert (1962), that is, the convarietas (convar.) and the botanical varietas (var.), were determined based on the descriptors mentioned above.

Seven characters of high heritability were selected for a separate phenotypical assessment of the genetic diversity (Tammes 1930). For some of the characters and the distinguished character states used for defining the morphological groups (Table 2), Vavilov (1926) presented a detailed analysis of their geographical distribution. They were also used in the flax classification completed by Elladi (1940). Accessions that were mixtures were not included in this survey; if off-types occurred in an accession, the character state of the dominating type was recorded.

During the six growing seasons of 1998-2004, environmental factors influenced some of the character state expressions. For these character states, inconsistent ratings occurred in successive years. For example, the petal colour states "light blue", "medium blue", "dark blue" and "violet" were sometimes difficult to distinguish. To avoid inconsistencies in assigning accessions to morphological groups, these ambiguous character states were combined into one character state called “blue”. Similar consolidations of ambiguous character states were undertaken for six of the seven characters used for this assessment (Table 2). As a result, character distinctions that appeared dependent on environmental influence, or which were difficult to determine consistently, were avoided.

After these consolidations, the analysed data distinguished seven characters and 19 character states (Table 2). For 2545 accessions, all data was available and summarised. Each of the 768 mathematically possible character state combinations (based on multiplication of the number of character states with each other) represented a morphologically and genetically distinct group. The frequency of these morphological groups among the 2545 accessions was determined. Each morphological group was assigned a number code which consisted of the combined number codes for the character states in the order of the characters as listed in Table 2.

Richness, that is, the number of morphological groups, and evenness (or concentration), that is, the frequency of representation of the identified morphological groups, were determined. Based on the assignment of each flax accession to a morphological group, and based on the botanical variety determination according to Kulpa and Danert (1962), qualitative and quantitative assessments of the diversity in the PGRC flax collection and trends in the diversity of North American flax cultivars were made.

Results

Diversity within the PGRC Collection

Within the 2,545 flax accessions, 79 morphological groups could be distinguished based on the descriptor assessment. This means 689 or 90% of 768 mathematically possible character state combinations were not found. Sorting the groups by the number of accessions assigned to each group allowed to visualize the two components of diversity (richness and evenness) within the PGRC flax collection (Figure 1).

The number of accessions in each group ranged from 528 accessions in the most frequent morphological group (rank number 1) to one accession representing each of the morphological groups with rank numbers 45 to 79. In other words, the distribution was uneven as the most frequent morphological group included 21.6% of the accessions (Table 3). The morphological group code ‘2122121’ of the most frequent phenotype indicated the following character state combination: indehiscent capsule, brown seed, blue petal, anther dark pigmented, filament white, style pigmented, no ciliation of capsule septum.

The three most frequent morphological groups, which were about 4% of the 79 morphological groups found, comprised more than 50% of the 2545 accessions (Table 3). The 20 most frequent morphological groups covered 99% of all accessions.

The 35 morphological groups represented by one accession originated from the eleven countries Afghanistan, Australia, Canada, Czechoslovakia, E-gypt, France, Hungary, India, Romania, Russia and USA. This indicated that unique germplasm originated from a wide range of geographical areas.

Determination of the infra-specific taxa also showed a high concentration towards certain groups. On the convariety level, the intermediate type (convar. *usitatissimum*) dominated the PGRC collection. Accordingly, mo-re than 50% of the PGRC flax accessions belonged to var. *usitatissimum* (Table 4). The next most frequent botanical varieties were var. *elatum-multicaule* (10%), var. *caesium* (9%) and var. *pupurascens* (9%). These four botanical varieties covered 90% of the PGRC flax collection. Similar to the grouping of the collection into morphological groups, the infra-specific classification pointed towards high concentration of certain pheno-types in the PGRC flax collection.

Diversity among North American Cultivars

The 61 North American flax cultivars represented thirteen different morphological groups (Table 3). With 61 accessions, the North American cultivars represented only 2.4% of the assessed germplasm of the PGRC collection, but their thirteen morphological groups represented 16.4% of the morphological groups. This indicated, in relative terms, more richness of diversity within the North American cultivars than within the world col-lection.

The most frequent morphological groups in the world collection were also the most frequent morphological groups found in the 61 North American cultivars (Table 3). The number of accessions in each morphological group of the North American flax cultivars ranged from 17 accessions in morpho-logical group number 1 to one accession in the three least frequent morpho-logical groups.

Change in morphological diversity in North American flax cultivars over time was quantified by determination of the number of morphological groups released within five twenty-year periods over the 20th century (Figu-re 2). In terms of morphological groups, the diversity appeared relatively constant. When looking at the botanical classification, a concentration on flax cultivars classified as *L. usitatissimum* convar. *usitatissimum* var. *usi-tatissimum* was observed over time (Table 1, Figure 2). With the decline of fibre flax in North America over the course of 20th century, accessions be-longing to convar. *elongatum* (fibre flax type) disappeared after 1980.

Comparison of the Flax Collection in the German (IPK) and Canadian (PGRC) Genebanks

The absolute and relative numbers of representation of each of the 28 botanical varieties defined by Kulpa and Danert (1962) in the IPK and PGRC genebank collections are shown in Table 4 and Figure 3, respectively. The representation of infra-specific taxa was comparable in the German and Canadian genebanks. Obvious deviations were the larger concentrations towards var. *usitatissimum* and the higher proportion of var. *pupurascens* in the PGRC collection. Two botanical varieties were missing from the PGRC collection (vars. *axumicum* and *candidum*) and two botanical varieties were missing from the IPK collection (vars. *pallidiflorum* and *pupureum*).

Discussion

Both approaches used to assess diversity in the flax gene-pool indicated a concentration towards certain phenotypes in the flax gene-pool. Similar assessment results were expected, as both methods were based on phenotypic characterisation of diversity. Compared to the morphological groups defined here, the classification of Kulpa and Danert (1962) is more natural as it used important quantitative characters such as plant height, technical stem length and seed weight for determination of the convarieties. These characters are closely associated to the evolutionary history of flax under domestication, resulting in a natural grouping reflecting evolution (Danert 1962). However, the character state distinctions are not discrete in quantitative characters, resulting in less repeatability when categorizing germplasm based on them compared to the more artificial distinction of morphological groups.

The assessment based on defined morphological groups has similarities to the infra-specific grouping in its methodology and it could be converted into a formal taxonomic system for grouping the flax gene-pool by assigning names to each of the 79 morphological groups defined by different character state combinations. The flax classification suggested by Howard (1924) used exactly the same characters listed in Table 2, except the ciliation of the septa. Howard (1924) used one additional character, seed size, described as bold seeds versus small seeds. However, Howard (1924) did not clearly define these character states. This points to two problems associated with formal infra-specific classifications: the inflexibility to integrate other characters and the possibility of inconsistency when applying such classifications by different researchers.

In this study, inconsistencies in the determination of the flax accessions belonging to var. *purprascens* are probably the reason for the discrepancy in its representation between the PGRC and IPK collections. Petal colour distinction between blue and red-violet, which is needed for distinguishing var. *purpurascens* from var. *usitatissimum,* was problematic.

The formalism associated with naming infra-specific groups has resulted in the rejection of formal infra-specific classifications in crop plants by many scientists (Mac Key 1981). It is evident that the use of formal taxonomic names does not always guarantee efficient communication about infra-specific diversity (Diederichsen 2004). Nevertheless, the usefulness of infra-specific classification in allowing a quick assessment of genetic diversity, for example in preparation of collecting missions, has been emphasized by Hanelt and Hammer (1995). Many publications showed the usefulness of taxonomy for collection management and diversity assessment (Hammer 1981, Hanelt 1988, Diederichsen 2004).

The advantage of using morphological groups instead of formal taxonomy is that new characters can be easily added to the definitions of such groups to gain a more detailed picture of the diversity within a genebank collection. Such studies can help to reveal the structure within botanical species (Vavilov 1931). Computer databases of well characterised collections allow extraction of information to categorise large amounts of germplasm by defining morphological groups. Such databases were not available when traditional taxonomic systems were developed, such as by Alefeld (1866). The name of the lowest infra-specific taxon delivers all characterisation information in one word to those researchers familiar with the system. A complete and detailed characterisation (phenotyping) of the germplasm is required for both types of diversity assessment.

The occurrence of only 79 of 768 mathematically possible character combinations in the PGRC flax collection may be due to two reasons: (1) the missing character combinations are very rare and, therefore, not represented in the PGRC collection; or (2) the missing character-combinations do not exist due to linkage or pleiotropic effects in some of the observed character states. The consequence would be that some character state combinations would be very rare or not possible at all. A detailed analysis of the frequency of character associations would be required to detect such linkages.

Morphological characters not included in this study, such as petal margin folding, could be used to further delimitate genetically distinct morphological groups. Also, molecular methods could be applied to detect genetic diversity within the morphological groups and may result in a finer resolution to assess genetic differences. A solely molecular approach may result in a very different grouping, as the associations between molecular and phenotypic diversity can be loose (Fu 2006, Diederichsen and Fu 2006).

Both approaches, infra-specific classifications and morphological groupings, could be used to establish a subset of a limited number of germplasm accessions capturing a maximum of morphological diversity, which is required to assemble a core collection (Frankel and Brown 1984).

Another application of the described methods can be the assessment of diversity within subsets of a gene-pool, demonstrated here by examining the 61 North American flax cultivars. A tendency to concentrate on certain phenotypes in the North American flax cultivars was observed after the 1940s. While the number of released cultivars increased, the number of phenotypical groups decreased. A molecular approach came to similar conclusions (Fu et al. 2003). This tendency may partly be due to the restriction to linseed breeding only after the 1930s and to the decrease in number of independent flax breeding programmes (Dillman 1936; Kennaschuk and Rowland 1995). However, the decrease is not drastic, as North American flax breeding programmes have consistently relied on introducing new germplasm from abroad (Kennaschuk and Rowland 1995).

This study demonstrated that a morphological characterisation of a genebank collection allows to extract information of relevance for genebank management, diversity preservation and plant breeding. Formal infraspecific classification has the advantage of historical stability, as it creates reference points in time. The rules for publishing formal names and depositing reference specimens result in such reference points as herbarium specimens and publications. The alternative method, an informal morphological grouping, allows for more flexibility. Both approaches are based on functional diversity and allow high throughput genetic diversity analysis of large genebank collections.

Acknowledgements

The author thanks Mr. Peter Kusters for maintaining the flax field plots and plant characterisations and Mr. Dallas Kessler for handling the germplasm and associated information. Financial support from the Saskatchewan Flax Development Commission at Saskatoon, Canada, the Agriculture Development Fund of Saskatchewan, Regina, and the Matching Investment Initiative of Agriculture and Agri-Food Canada, Ottawa, is greatly acknowledged. Many thanks to Dr. K.W. Richards and Mr. R.K. Gugel for comments on an earlier version of this manuscript.

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Table 1. Sixty-one North American flax cultivars from the PGRC collection, their botanical determination and morphological group code.

Cultivar	CN accession Number	Country	Type	Year of release[a]	Convar.	Var.	Morphological group code[b]
Crown Canada	97035	Canada	Linseed	1910	*usitatissimum*	*usitatissimum*	2122121
Novelty	97392	Canada	Linseed	1910	*usitatissimum*	*caesium*	2122121
Diadem	19159	Canada	Linseed	1910	*usitatissimum*	*lutescens*	2112112
Ottawa 770B	19158	Canada	Linseed	1910	*usitatissimum*	*pekinense*	2313112
Ottawa 829-C	19157	Canada	Linseed	1910	*elongatum*	*crispum*	2313112
Rocket	97299	Canada	Linseed	1947	*usitatissimum*	*usitatissimum*	2122111
Raja	97300	Canada	Linseed	1953	*elongatum*	*elatum-multicaule*	2122122
Cree	33384	Canada	Linseed	1962	*usitatissimum*	*purpurascens*	2142121
Noralta	33386	Canada	Linseed	1965	*usitatissimum*	*caesium*	2122111
Redwood 65	33388	Canada	Linseed	1965	*usitatissimum*	*usitatissimum*	2122221
Linott	41190	Canada	Linseed	1966	*usitatissimum*	*purpurascens*	2142121
Dufferin	33397	Canada	Linseed	1975	*usitatissimum*	*usitatissimum*	2122222
Mcgregor	39034	Canada	Linseed	1981	*usitatissimum*	*purpurascens*	2142221
Norlin	52732	Canada	Linseed	1982	*usitatissimum*	*usitatissimum*	2122122
Norman	42943	Canada	Linseed	1984	*usitatissimum*	*usitatissimum*	2122222
Vimy	44316	Canada	Linseed	1986	*usitatissimum*	*caesium*	2142121
Andro	18977	Canada	Linseed	1988	*usitatissimum*	*usitatissimum*	2122121
Somme	18980	Canada	Linseed	1989	*usitatissimum*	*usitatissimum*	2122121
Flanders	18979	Canada	Linseed	1989	*usitatissimum*	*usitatissimum*	2122222
AC Linora	19005	Canada	Linseed	1990	*usitatissimum*	*usitatissimum*	2122121
AC McDuff	19003	Canada	Linseed	1993	*usitatissimum*	*usitatissimum*	2122222
AC Emerson	19004	Canada	Linseed	1994	*usitatissimum*	*usitatissimum*	2122121
CDC Triffid	19016	Canada	Linseed	1994	*usitatissimum*	*usitatissimum*	2122121
CDC Arras	18976	Canada	Linseed	1998	*usitatissimum*	*usitatissimum*	2122221
AC Carnduff	18975	Canada	Linseed	1998	*usitatissimum*	*usitatissimum*	2122222
CDC Bethune	18974	Canada	Linseed	1998	*usitatissimum*	*usitatissimum*	2122222
Blanc	97418	Canada	Fibre	1918	*usitatissimum*	*lutescens*	2112112
Liral Dominion	97805	Canada	Fibre	1945	*usitatissimum*	*usitatissimum*	2122121
Stormont Goss. Fiber	98931	Canada	Fibre	1947	*elongatum*	*elatum-multicaule*	2122222

Wiera Fiber	98933	Canada	Fibre	1951	*elongatum*	*elatum-multicaule*	2122222
Liral Prince	98945	Canada	Fibre	1947	*elongatum*	*elatum-multicaule*	2122122
N.D. Resistant No. 52	97467	USA	Linseed	1908	*usitatissimum*	*usitatissimum*	2122121
N.D. Resistant No. 114	97466	USA	Linseed	1912	*usitatissimum*	*purpurascens*	2142122
Pilar	97389	USA	Linseed	1919	*usitatissimum*	*usitatissimum*	2122121
Winona	97464	USA	Linseed	1920	*usitatissimum*	*caesium*	2122222
Buda	97421	USA	Linseed	1921	*usitatissimum*	*caesium*	2122111
Linota	97403	USA	Linseed	1925	*usitatissimum*	*usitatissimum*	2122121
Bison	33399	USA	Linseed	1925	*usitatissimum*	*caesium*	2122221
Newland	97401	USA	Linseed	1927	*usitatissimum*	*caesium*	2122122
Redwing	97415	USA	Linseed	1928	*usitatissimum*	*caesium*	2122221
Pinnacle	97574	USA	Linseed	1931	*usitatissimum*	*lutescens*	2112111
Bolley Golden	19160	USA	Linseed	1932	*elongatum*	*flavescens*	2213111
N.D. 2-B-5128 Sel	98520	USA	Linseed	1943	*usitatissimum*	*usitatissimum*	2122122
Viking	97748	USA	Linseed	1945	*usitatissimum*	*luteum*	2213111
Victory	98819	USA	Linseed	1946	*usitatissimum*	*lutescens*	2112112
Sheyenne	98840	USA	Linseed	1947	*usitatissimum*	*usitatissimum*	2122121
Dakota	97815	USA	Linseed	1947	*usitatissimum*	*usitatissimum*	2122122
Redwood Hi-oil Bulk	98957	USA	Linseed	1951	*usitatissimum*	*caesium*	2122121
Bolley (1085 x 1134)	98061	USA	Linseed	1951	*usitatissimum*	*usitatissimum*	2122221
Marine (C.I. 975 x Sheyenne)	98841	USA	Linseed	1951	*usitatissimum*	*usitatissimum*	2122221
Victory Sel. No. 3256 (Norland)	97914	USA	Linseed	1954	*usitatissimum*	*lutescens*	2112112
Arny (Cryst. x Redson)	98857	USA	Linseed	1961	*elongatum*	*elatum-multicaule*	2122121
Windom	98236	USA	Linseed	1962	*usitatissimum*	*usitatissimum*	2122121
Summit (C.I. 980 x Zenith)	98310	USA	Linseed	1963	*usitatissimum*	*usitatissimum*	2122111
Nored - B-5128 x Redson	98527	USA	Linseed	1968	*usitatissimum*	*caesium*	2122111
Norstar	33400	USA	Linseed	1969	*elongatum*	*elatum-multicaule*	2122121
Foster ND14a (1605 x Minerva)	98821	USA	Linseed	1969	*usitatissimum*	*choresmicum*	2242221
Culbert	33992	USA	Linseed	1978	*usitatissimum*	*caesium*	2122121
J.W.S. Fiber	97440	USA	Fibre	1924	*usitatissimum*	*caesium*	2142122
F.I. No. 3	97575	USA	Fibre	1931	*usitatissimum*	*caesium*	2122221
Cirrus	97672	USA	Fibre	1932	*usitatissimum*	*usitatissimum*	2122221

[a] *Year of realease according to Dillman (1936) and Kennaschuk and Rowland (1995).*
[b] *Numerical code listing the single codes for each characters state in order and value as presented in Table 2.*

Table 2. Characters and frequencies (number of accessions) of character states in raw data and after combining selected character states for 2545 Linum usitatissimum accessions at Plant Gene Resources of Canada.

Character	Raw data		Consolidated character states		
	State	Frequency	State	Code	Frequency
(1) Capsule dehiscens	Dehiscent	4	Dehiscent	1	4
	Medium opened	474	Indehisecent	2	2542
	Slightly opened	1181			
	Weak	798			
	Indehiscent=9	88			
(2) Seed colour	Light brown	5	Brown	1	2413
	Medium brown	2403			
	Dark brown	5			
	Yellow	101	Yellow	2	101
	Olive	21	Olive	3	21
	Mottled brown/yellow	10	Mottled brown/ yellow	4	10
(3) Petal colour	White	258	White	1	258
	Light blue	78	Blue	2	1949
	Medium blue	1606			
	Dark blue	21			
	Violet	244			
	Pink	11	Pink	3	11
	Red-violet (Lavender)	327	Red-violet	4	327
(4) Anther colour	White	4	White	1	4
	Light blue	4	Dark pigmented	2	2339
	Blue	836			
	Dark blue	5			
	Violet	5			
	Greyish (tourquis)	1489			
	Cream-coloured (Yellow)	157	Yellow/orange	3	202
	Orange	45			

(5) Filament colour	White	1699	White	1	1699
	Light blue	3	Dark pigmented	2	846
	Blue	778			
	Dark blue	36			
	Violet	29			
(6) Style colour	White	843	White	1	857
	Yellow	14	Dark pigmented	2	1688
	Light blue	1			
	Blue	1460			
	Dark blue	219			
	Pink	5			
	Violet	3			
(7) Ciliation of septa	Cilia absent	1764	Cilia absent	1	1764
	Cilia present	781	Cilia present	2	781

Table 3. Frequency of morphological groups covering 99% of 2545 flax accessions. Their distribution over the four flax convarieties and their occurrence within 61 North American flax cultivars.

Morphological group code[a]	Number of accessions	Cumulative proportion of accessions included (%)	Frequency rank	Convariety					North American cultivars
				crepitans	*elongatum*	*usitatissimum*	*mediterraneum*	Not determinated	
2122121	528	21,6	1		34	430	41	23	17
2122111	399	37,9	2		26	322	35	16	5
2122221	376	53,3	3		35	316	16	9	8
2122222	255	63,7	4		101	149	2	3	9
2122122	172	70,8	5		36	133		3	6
2142121	110	75,3	6		3	96	10	1	3
2122112	98	79,3	7		16	78	2	2	
2112112	72	82,2	8		32	40			4
2142222	53	84,4	9		16	35		2	
2142221	51	86,5	10		1	49	1		1
2142111	49	88,5	11			39	8	2	
2113111	40	90,1	12		2	36		2	
2122211	38	91,7	13			37		1	
2213111	37	93,2	14		3	31	2	1	2
2142122	35	94,6	15		7	26	1	1	2
2112111	34	96,0	16		7	27			1
2113112	20	96,8	17		1	8	10	1	
2222221	16	97,5	18			15	1		
2123221	14	98,0	19			14			
2213112	12	98,5	20		3	6	3		
2123121	10	98,9	21			9	1		
2313112	10	99,3	22		1	8		1	2

[a] *Numerical code listing the single codes for each characters state in order and value as presented in Table 2.*

Table 4. Number of accessions of infraspecific taxa of cultivated flax (*Linum usitatissimum* L. subsp. *usitatissimum*) at the Canadian (PGRC) and German (IPK) national genebanks.

Convarietas	Varietas	PGRC	IPK
crepitans (Boenningh.) Kulpa et Danert		10	27
	crepitans	10	27
elongatum Vav. et Elladi		370	579
	crispum Vav. et Elladi	7	13
	elatum-multicaule Schur (syn.: *elongatum*)	275	451
	flavescens Alef.	8	2
	pallidiflorum Vav. et Elladi	6	-
	regale Scheidw.	46	110
	roseum Vav. et Elladi	28	3
usitatissimum		2208	882
	albidum How. et Rahm.	3	5
	albocoerulum How. et Rahm.	8	19
	album How. et Rahm.	20	10
	angustipetalum Vav. et Elladi	5	11
	axumicum Cif.	-	7
	caesium How. et Rahm.	258	471
	candidum Vav. et Elladi	-	1
	choresmicum Vav. et Elladi	15	1
	elegans Vav. et Elladi	3	3
	elladii Kulpa et Danert	24	4
	indicum How.et Rahm.	45	19
	lutescens How. et Rahm.	93	6
	luteum How. et Rahm.	35	8
	pekinense Vav. et Elladi	21	2
	pratense How. et Rahm.	24	4
	purpurascens Vav. et Elladi	244	3
	purpureum How. et Rahm.	3	-
	usitatissimum	1407	308
mediterraneum (Vav. ex. Elladi) Kulpa et Danert		160	118
	macranthum Vav. et Elladi	29	1
	macrocarpum Alef. (syn.: *mediterraneum*)	110	117
	palaestinum Vav. et Elladi	21	-
Total		**2748**	**1606**

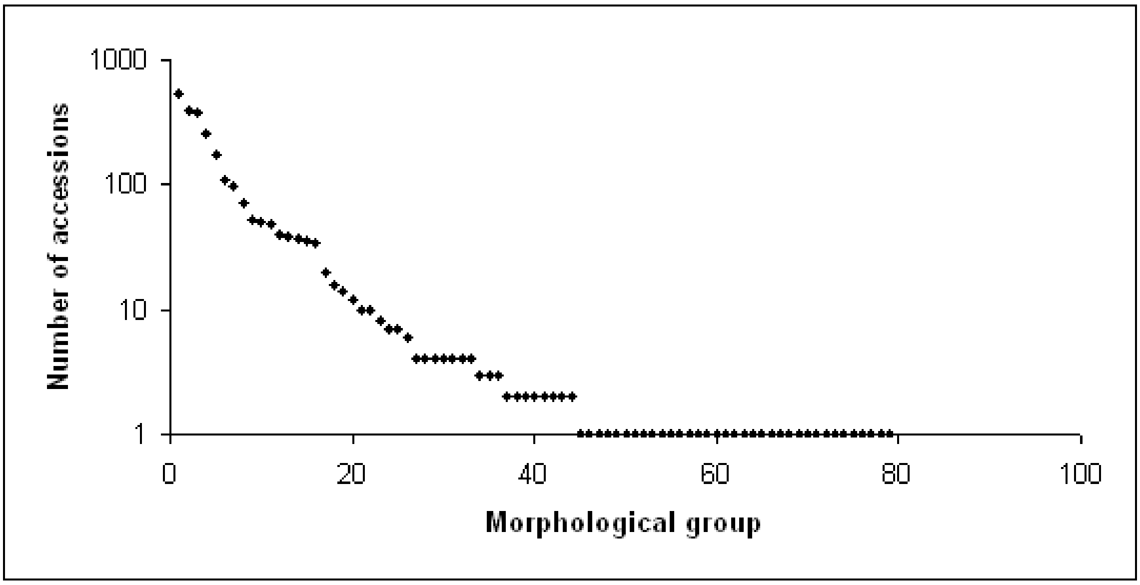

Figure 1. Diversity of 2545 accessions of cultivated flax in the Plant Gene Resources of Canada collection. The morphological groups are sorted and numbered in descending order based on the number of accessions included in each morphological group.

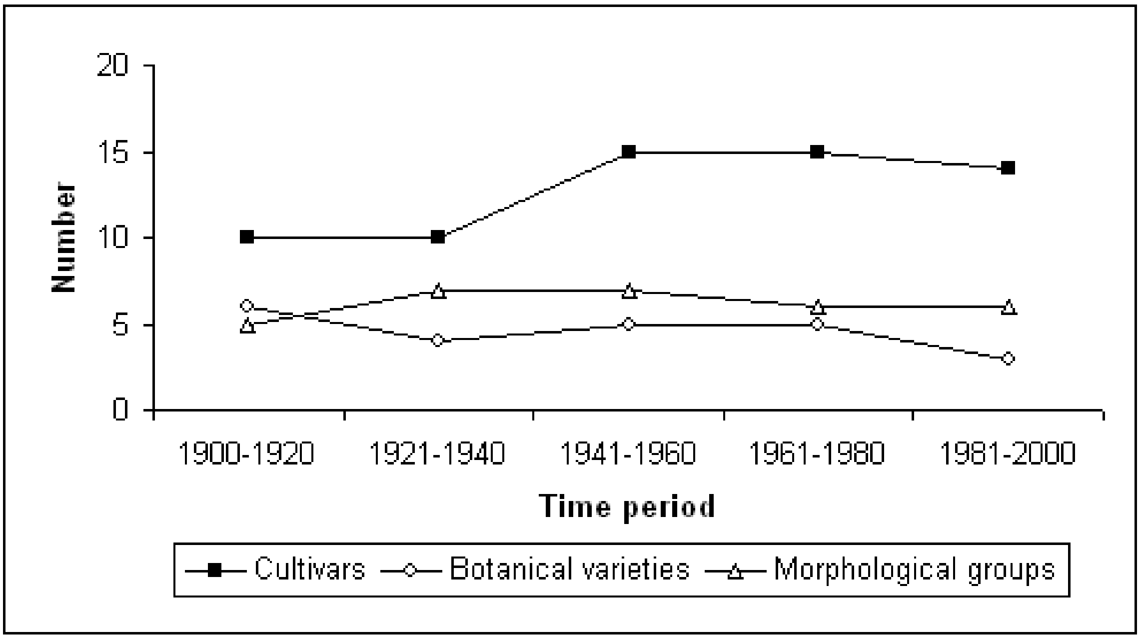

Figure 2. Number of North American flax cultivars released in 20 years periods of the 20th century and the numbers of botanical varieties and morphological groups these cultivars represent.

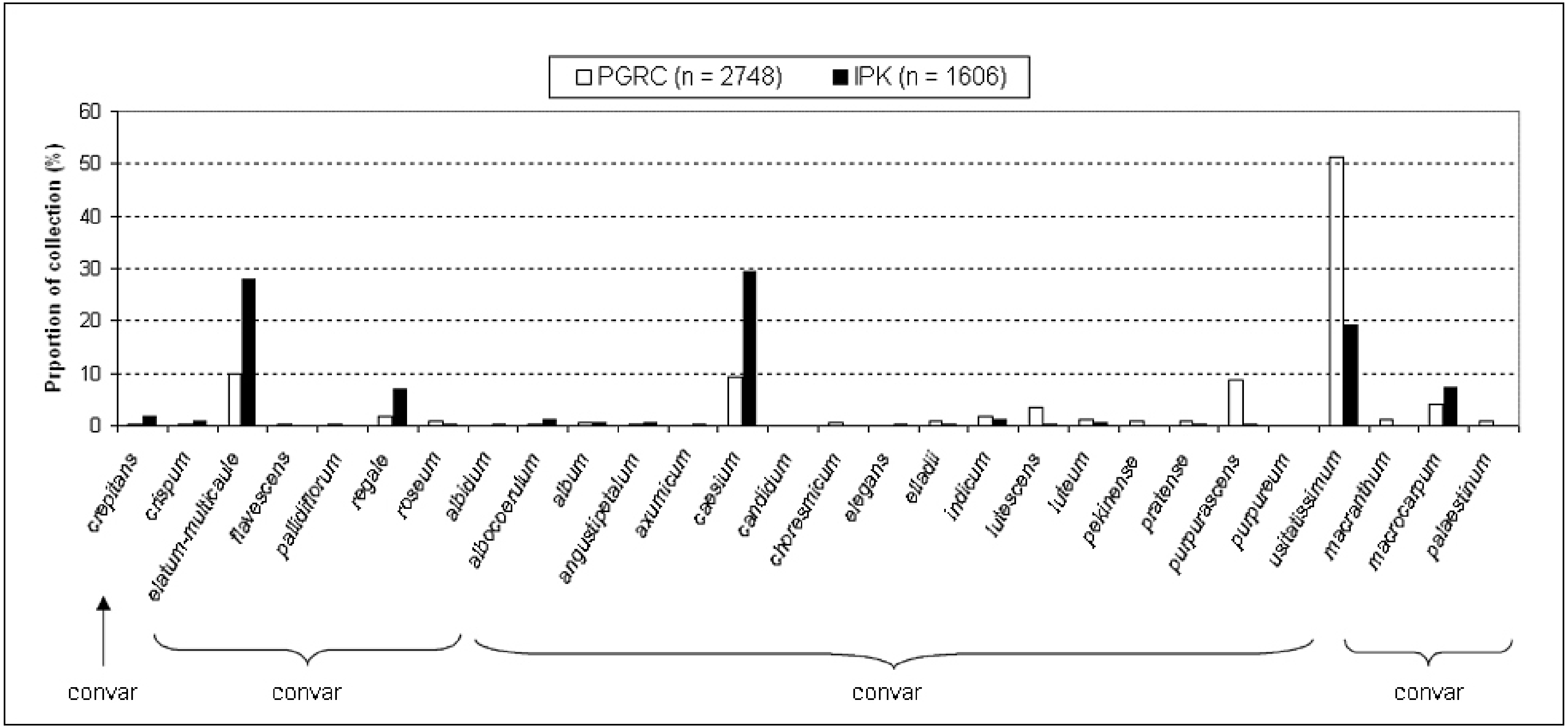

Figure 3. Relative representation of infraspecific taxa of cultivated flax (*Linum usitatissimum* subsp. *usitatissimum*) in the collections of Plant Gene Resources of Canada (PGRC), Saskatoon, Canada, and Leibniz Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK), Gatersleben, Germany.

REPORT OF THE THIRD COLLECTING MISSION IN ALBANIA, AUTUMN 1994

Th. Gladis, K. Hammer, P. Perrino, W. Podyma and L. Xhuveli

The third joint collecting mission and evaluation of plant genetic resources in Albania was undertaken by staff members of genebanks in Germany, Italy and Poland together with a specialist of the host institution in Tirana. Genetic erosion of landraces and wild relatives of cultivated plants will be likely-speeded up during the process of reintegration of Albania into the European development of economy and tourism. As this is a comparably isolated part of the Mediterranean centre of genetic variability, the estimation of diversity in plant genetic resources is high. The region is very poor; farmers are not able to apply modern techniques, and to buy fertilizers or pesticides. Two factors limit the expectation of finding high plant genetic resources diversity: the high preference of Albanian people for meat consumption, and the influence of introduced modern cultivars of all main crops (Hammer et al. 1995).

The northern part differed very much from the south in climate, soil conditions, culture, tradition and utilization of crops. In the south there was more bread wheat, maize, vegetables, forage crops and spices; these were less common in the north, where cereals dominate, mainly maize and rye and in some cases wheat. In the north the most often used forage crop was alfalfa. Local populations of Peshkopi were grown on a wide area. The beans and traditional corn accessions very often showed white seeds. This colour seemed to be preferred (even in clothing of the farmers). The mission yielded accessions of landraces, wild relatives of crops and weeds. The material was divided as far as possible and will be available after reproduction for screening and other purposes. The recentmission was undertaken to continue the joint activities in areas not covered during the previous mission in 1993 (Hammer et al. 1994)

Genetic erosion, caused by burning and overgrazing, was lower than in other regions of the Mediterranean genecentre. Agriculture was present throughout the collecting area, and in the mountains, fields and home gardens are extremely small. Few crops species with high variable populations were found there, whereas in the lowlands, field size was larger and crop

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uniformity higher than in the highlands. In the extreme south, the influence of Greek culture was found to be very strong regarding diversity of vegetables in house gardens. There, relatively many spices are used, such as *Anethum, Anthriscus cerefolium, foeniculum, Levisticum, Trigonella foenum-graecurn* and others. Viticulture and fruit plantation which have been present everywhere were damaged on a wide scale after the political changes.

At the time of our mission the mountains were still rich in rare cereals, but of course they could not be found as frequently as in 1941/42 when Stubbe (1982) carried out his collecting mission. *Triticum monococcum, T. turgidum* and other relic cereals were well known to the farmers and might be found by more intensive searches, perhaps in the eastern part of the country. During the mission in the eastern part one sample of an old local wheat cultivar named 'Rapsall', which belongs to *Triticum turgidum,* was collected (in Verdove village near the town of Pogradec). Variation in *Secale cereale* is high, and the seed samples in many cases contain seeds of weed species, such as *Agrostemma githago, Bifora radians, Lolium temulentum* and *Ranunculus arvensis.* These are indicators of traditional agriculture, which are extinct or endangered in most other European countries. Even in the mountains, only a single accession of *View ervilia* was found. The most important legume was *Phaseolus vulgaris,* followed by nearly equal accession numbers of *Cicer arietinum, Lens culinaris, Phaseolus coccineus, Pisum sativum* and two different types of *Vigna unguiculata.* More rare are *Lathyrus sativus* and *Vicia faba.* Traditional crops for cleaning brushes were *Kochia* (two accessions) and *Sorghum saccharatum* var. *technicum.* A relic vegetable is the cultivated *Rumex patientia.* In contrast to the findings in Sardinia (Gladis *et al.* 1994), *Allium* cf. *ampekprasum* is cultivated, sometimes close to beds with *A. porrum, A. cepa* or *A. sativum.* Vegetables that are very common in other Mediterranean countries, such as *Beta, Cichorium, Daucus* or *Solatium melongena,* were observed in only a few cases during the collecting mission. Besides traditional crops, the influence of modern cultivars from Northern Europe were found in tomatoes or in maize. A very interesting fruit-bearing shrub or small tree was the buffalo berry, *Shepherdia argentea.* This American species was planted as a fence around home gardens. Its fruits were used fresh, and have been found sometimes in the market of Tirana.

In total, 354 samples representing 75 different species were collected. A summary of the main groups out of this material is presented in Table 1.

The collected material will be integrated and maintained in the genebanks in Bari, Gatersleben, Radzikow and Tirana for storing after reproduction. It will be included in specific evaluations and other research programmes. Further activities will concentrate on interesting regions not touched or not intensively checked during the previous missions.

Table 1. Samples collected in the third collecting mission to Albania, 1994

Crops	Number of accessions
Avena spp.	13
Hordeum vulgare	11
Secale cereaie	13
Triticum spp.	14
Zea mays	26
Other cereals and relatives	3
Cereals (total)	80
Phaseolus vuigaris	57
Other legumes	32
Legumes (total)	89
Abelmoschus esculentus	6
Allium spp.	28
Brassica spp.	8
Capsicum spp.	26
Citruiius lanatus	5
Cucumis spp.	10
Cucurbits spp.	10
Lycopersicoti esculentum	13
Other vegetables	20
Vegetables (total)	126
Crops used as spices, fruits, medicinal plants, condiments and ornaments	23
Sorghum saccharatum var. *technicum*	5
Other technical plants	2
Agrostemma githago	12
Other weeds and wild plants	17
Total	59
Total samples collected	**354**

Acknowledgement

The authors want to express their thanks to IPGRI for financing the mission and to all people who helped during the weeks of the collecting mission.

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REVIEW ON WHEAT BREEDING AND GENETIC RESOURCES IN ALBANIA

Lufter Xhuveli

Abstract

For centuries the cultivation of wheat was a predominant activity in Albanian agriculture. Due to favorable geographical and climate conditions as well as the tradition and research, a considerable number of wheat varieties have been cultivated in all over the country. Collecting and conservation of wheat landraces and its wild relatives have attracted the interest of many national and international breeders and scientists, since the beginning of the 20th century. Research efforts to increase wheat yield, protein content, resistance lodging,and time of maturity made the conservation of autochthonous wheat genes and the local wheat landraces very important for the future of wheat breeding in Albania. This paper aims to present background information on the history of wheat introduction and distribution in Albania, wheat genetic resources, its breeding, and the scientific research carried out by Albanian researchers.

Key words:
wheat, genetic resources, breeding, varieties, research, Triticum sp.

Introduction and History of Wheat in Albania

According to archeological and historical studies, the Illyrians, predecessors of the Albanians, are amongst the oldest people of the ancient times inhabiting the Mediterranean areas. The Albanoi tribe was a living proof of the connection between the Illyrians and Albanians, and its name served as the origin of the names Albania and Albanians (Albanian Encyclopedic Dictionary, 1985). As early as the 4th Century BC, the Illyrians founded several states, so called Taulanti, Encheleae, Ardiaei and Mollosia.

It is documented that the development of agriculture and crop cultivation in Albanian territories started during the Neolithic Age in 6000 years BC (Anamali, 1979; Ceka, 2005). Old agricultural tools, made of bones and stones, and ceramic utensils used for storage of cereals, seeds and other goods discovered in the prehistoric tombs, bear testimont the ancient origins of agriculture in what is now Albania.

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Figure 1: Carbonized seeds of *Triticum monococcum* found in Maliq, Albania (Xhuveli & Schultze-Motel, 1995)

Figure 2: Carbonized seeds of *Triticum dicoccon* found in Maliq, Albania (Xhuveli and Schultze-Motel, 1995)

During archeological excavations in the period 1958-1962, carried out at the site of an ancient Illyrian civilization settlement of the Neolithic Age (V-III Millennium BC) in Maliq, district of Korca, in south-eastern Albania (20 48' E, 40 25 N), carbonized remains of cultivated plants were discovered. The materials found were carbonized seeds of einkorn (*Triticum monococcum* L. 2n=2x=14) 4.5-6 mm long (Fig. 1), emmer (*T. dicoccon* Schrank, 2n=4x=28) 5-7 mm long (Fig. 2) and barley and small legumes (Xhuveli and Schultze-Motel, 1995).

Einkorn and emmer wheat were probably introduced into the south Balkan Peninsula area from Asia Minor and other Mediterranean areas, which were important centers of origin or genetic diversity of many cultivated crops

(Vavilov, 1992). It seems plausible that several of these cultivated crops might have been introduced into Albania via the northern part of Greece or Thessaly, geographically the central part of mainland Greece, where einkorn and emmer have been common since the 6th millennium BC (Kroll, 1981; Hopf, 1961).

It is possible that einkorn and emmer where introduced into Albania as early as 4000-5000 BC. Due to its high resistance to drought climate and its ability to reproduce in poor soils, einkorn has proven to be one of the most important crops of ancient Illyrians (Qafezezi, 1957). It was used primarily as food for animals. Until the 1960’s einkorn was still cultivated on 5000-7000 ha per year as a common crop in hilly mountainous areas of southern Albania (Statistical yearbook, 1958). Nowadays einkorn is almost a relict crop. During five collecting missions, organized between 1993 and 1996, only four samples of einkorn were found in the vicinity of Tepelena and in Berati district, in the mountainous regions of southern Albania (Hammer et al., 1995). *T. dicoccon* was the most important food crop during the Neolithic and early bronze ages.

Traces of naked tetraploid wheat have been present in the Near East since the 7th millennium BC, whereas in Greece traces date back as early as the 5th millennium BC (Zohary & Hopf 1993). During the following centuries hulled emmer wheat could not resist the competition of advanced naked and free-threshing wheat types, and as a consequence began to be gradually replaced. However, it was still being cultivated in Albania in very small areas until the last decades of the 20th Century.

Durum wheat was well adapted and quickly spread through the Mediterranean region. This is the main reason why countries of the Mediterranean area, including Albania, were long considered as durum growing countries. Tetraploid free-threshing wheat or *Triticum turgidum* (2n=4x=28) were cultivated during ancient times in Albania, particularly on hilly slopes and relatively dry areas until 2-3 decades ago. *T. turgidum* conv. *durum* (Desf) MackKey or *T.turgidum* Desf. was much more widespread and continues to be grown. Less extensively adopted was *T. turgidum* conv. *turgidum* (L) MackKey or *T. turgidum*, which has been not cultivated in the country since the 1960’s.

Taking into consideration the vicinity to the Near East it can be stated that Albania is one of the oldest countries in the world adopting crop cultivation including wheat. Based on written documents, different Illyrian provinces such as Kaonia (current Saranda), Spinarica, Pyrgu and Ishmi, located respectively in the deltas of the rivers Vjosa, Shkumbini and Erzeni have exported wheat to neighboring countries since the 2nd and 3rd century AD. During his research in Albania, the albanologist Karl Patsch discovered in 1900 in the old Illyrian city of Amantia a stone slab with writings reporting that in 169 AD some 110 tons of wheat and 68 tons of barley were exported to Rome (Qafezezi, 1957).

Trade in wheat grain was especially intensive in city states like Raguza (current Dubrovnik in Croatia), Venetia (Italy), and Corfu (Greece). According to a document of 5 March 1347 (Acta et Diplomatica, II. 31), the Council of Raguza had decided to buy wheat from Albanian ports at a price of 28 grosh for every wheat star (grosh and star were respectively the currency and weight measurements used at that time in Raguza). Another document from the same source, mentions that the export of wheat from the Albanian town of Vlora to Corfu was carried out by boats. According to Castelani (1941), the Italic people have learned bread-making by the old Illyrian tribe of Mesap.

During the second half of the 20th century, drastic changes took place in the use of wheat cultivars, technologies of production and areas of cultivation. Until the beginning of the 20th century, wheat cultivar grown consisted of indigenous durum wheat landraces. According to Xhuveli (1987) more than 80% of the wheat area in 1961 was cultivated with durum wheat, the rest was grown with soft, hexaploid *T. aestivum* wheat cultivars. In the following decades, durum wheat was rapidly replaced by new hexaploid wheat cultivars with higher productivity.

Wheat Genetic Resources

There are several collections within the country, including the central gene bank (established in 1998 in Tirana), which preserves a total of about 10,000 wheat accessions, including wild relatives. These collections were established and completed in the course of the last 50 years by collecting germplasm and by introducing foreign germplasm from gene banks in Europe and other countries. Unfortunately, a large part of the wheat collection that was stored at the Agricultural University (estimated at ±2000 accessions) was destroyed during the unrests of 1997.

Three major phases in the collection of the Albanian wheat germplasm can be distinguished. The first collection mission dating from 1941-1942 was headed by Hans Stubbe and covered Albania, Greece and Crete (Stubbe, 1982). In 1941, 289 different accessions were collected, 162 of them belonging to *Triticum* spp. Of these 154 are still alive: 96 *T. aestivum*, 17 *T. durum*, 5 *T. turgidum*, 35 T. *monococcum* and one *T. dicoccon*. This germplasm is stored at the Gatersleben Gene Bank in Germany.

During the second phase 1956-1961 the staff the Agricultural Research Institute of Lushnja, discovered a considerable number of indigenous wheat accessions including 11 local varieties of *T. aestivum,* 13 of T. *durum* 13 of T. *turgidum* and *T. monococcum*, which were collected and preserved (Celiku, 1962; Mero, 1965; Gozhita, 1982).

The third phase consists of five multi-crop collecting missions during 1993-1996, organized jointly by the Agricultural University of Tirana in cooperation with scientists from Germany, Italy and the USA, during which a total of 19 cultivated wheat accessions were collected. These missions also collected eight samples of wild wheat relatives including *Aegilops geniculata* Roth (*Ae. ovata* L.), *Aegilops triuncialis* and *T. villosum* (Hammer et al., 1994; Gladis et al., 1995).

Figure 3: Prof. Lufter Xhuveli (left) and Prof. Karl Hammer (center) during a collecting mission in Albania (summer 1995).

Besides being stored within the country, Albanian germplasm is also conserved in several gene banks located outside the country, at Gatersleben in Germany, at the N.I. Vavilov All-Russian Scientific Research Institute of Plant Genetic Resources (VIR) in Russia, at NSGC Aberdeen in Idaho-USA, and at ICARDA in Syria, (Xhuveli, 1994).

The largest part of the Albanian wheat collection reflects because of introductions from other countries such as Italy, Germany, Russia, Mexico, France, Turkey, and Asia. Some cultivars, well known for their resistance to lodging and belonging to the Norin group ('Norin 10') contain the two most important semi dwarfing genes (Gale et al, 1975). The introduction of US germplasm in 1978 was facilitated by the FAO and especially by the kind support of Miss E. Benett (expert on plant genetic resources of FAO), as at the time Albania did not have diplomatic relations with the USA.

Using the germplasm collected during the 1941 missions in Albania by H. Stubbe and by the international team in 1993, collected mostly at the same sites even though 52 years apart, quantitative investigations have been undertaken to study the degree of wheat genetic erosion during this period. Erosion of genetic diversity were be estimated at the country level and for different regions, for sites, as well as for specific trait levels. A dramatic, strong and multi-faceted process of genetic erosion could be determined (Hammer et al., 1996). *T. dicoccon*, very much a relic crop in 1941 when only one sample was collected, in 1993 could not be located at all. *T. turgidum* and *T. durum*, from which five and 18 samples respectively were still collected in 1941, could also no longer be found in 1993. The level of genetic erosion was quantified at 72.4% in general and at 82% for *T. monococcum* (Hammer and Xhuveli, 2002).

Wheat Breeding in Albania

The climatic conditions of Albania are favorable for the cultivation of a wide range of crops including wheat. It is mainly a mountainous and hilly country with an average altitude of 708 m above sea level. Albania's climate is characterized by dry and hot summers and mild and wet winters. The annual mean temperature varies from 10.5-11^{o}C for the North-Eastern parts to 17.6^{o}C for the Western Mediterranean lowland area. Rainfall ranges from 638 to 3094 mm with an average rainfall per annum of 1430 mm.

Wheat breeding in Albania started at a relatively late date compared to other European countries. Until the mid 20th century only empirical wheat breeding was carried out by Albanian farmers. They selected the wheat types with desired phenotypic characteristics and expressing adaptation to the climate and soil conditions. Besides the old wheat einkorn and emmer types, the most widespread of the wheat landraces in Albania have been: 'Zhulica e Kuqe', 'Zhulica e Bardhe', 'Kutruli', 'Cube' and 'Koker Vogel i Shkodres' for *Triticum aestivum*; 'Rapsall', 'Karabash', and 'Gruna Madhe', 'Mavrogani', 'Vendi i Kuq i Gjirokastres' and 'Cub i Bardhe' for *Triticum turgidum* (Tashko, 1940; Permeti, 1970); 'Hoti' and 'Trimin' for *Triticum durum*. According to an observation made in 1959 (Celiku, 1962), 44 local wheat varieties (landraces)were planted at this time in Albania. However, these old wheat landraces were not suitable for cultivation under high-input conditions.

The increased use of fertilizers, herbicides, irrigation, drainage, farm machinery etc. required new wheat cultivars with higher yields, and improved harvest indices in order to produce more grains and less straw, as well as with resistance to lodging and diseases, with earlier maturity, and other desirable agronomic characteristics.

The first step on the road to increasing wheat production was conducting field trials for several years on the imported new varieties from countries such as Italy, Mexico, and the former Soviet Union. Slowly, during subsequent years the best of these imported varieties came to gradually replace the old wheat landraces. As a consequence, until 1985 the wheat sowing area was largely dominated by Italian cultivars. Mentana was one of the first Italian cultivars, introduced after 1930s. Later on, especially after 1950, other Italian cultivars were introduced, such as Tevere, Abbondanza, San Pastore, Strampelli, Mec, and the durum wheat Creso, For almost 15 years Strampelli was the most successful cultivar, increasing coverage from 19.5% of the national wheat area in 1973 to 62.3% in 1976, and finally decreasing to 28% in 1980.

During the "Green revolution" era Mexican cultivars such as Penjamo 63, Siete Cerros, Sonora 64, etc, were introduced and played an important role, to increase wheat production in Albania, especially during the period of 1970-1985, covering 10-30% of all wheat area.

During 1931-1932 the first experimental wheat field trial was carried out. In 1948 the first agricultural experimental station was established in Tirana, with wheat experiments as part of the research mission. Wheat breeding was identified as one of the scientific activities of the two centers that were established later on: the Tirana Agricultural University in 1951, and the Agricultural Research Institute of Lushnja, which was established in 1952 in a typical agricultural region.

Normally, five stages were distinguished in Albanian wheat breeding programs: choice of parents for crossing from the wheat collection; creation of genetic variation through crossing of parental plants; selection among the hybrid progenies; purification and maintenance of new homozygous wheat lines; testing of new wheat lines in the network of field comparison trials for agronomical and ecological characteristics. The Pedigree Method is the main method used for wheat breeding. In special cases, the backcrossing method, the mutagenesis and the acceleration seed multiplication of hybrid progenies have been used.

For the evaluation and approval of new wheat varieties and for official testing in the field comparison trials, a special National Committee was established to register the most successful new cultivars in the Official Catalog (Official Catalogue of Species and Varieties, 2000 and 2005).

The first wheat cultivars created by Albanian research centers started to be cultivated widely after 1970. Starting from 1975 onwards Albanian cultivars have covered 15-35% of the wheat area every year in the country. The most widespread Albanian wheat cultivars during the last 30 years are 'Dajti', 'LBZ', 'Kamza 9', LVS 93, 'LP3/3', 'Cerma 22-78' and L 22-1' for *T. aestivum*; and 'Lushnja 74', 'Kamza' and 'C-178' for *T. durum*

Table 1: The Albanian Wheat Cultivars registered in the Official Catalogue of Species and Varieties, 2000, 2005

No.	Name of the Cultivar	Year of Registration	Institution	Breeders	Characteristics
Triticum aestivum					
1	Dajti	1976	AUT[a]	M. Përmeti, Xh. Shima	E[d], A[f]
2	Kamza 9	1976	AUT	M.Përmeti, L. Xhuveli, H. Sulovari	L, A
3	LBZ 2	1982	ARIL[b]	S. Gozhita	E, A
4	Ciano X Jubileu	1982	ARIL	S. Gozhita	½ E
5	Lp.3-3	1982	ARIL	S. Gozhita, M. Çela	½ E, A
6	C22-78	1984		M. Përmeti, Xh. Shima	½ E, NA[g]
7	Nikla 886	1987		M. Përmeti	E, A
8	Nikla 684	1987		M. Përmeti	E, 1/2A
9	Kalliarta	1990	ARIL	S. Gozhita, V. Malo	½ E , A
10	David X Mec	1992	ARIL	Xh. Shima, M. Çela	E, A
11	Kamza 19	1994	AUT	L. Xhuveli, H. Sulovari	E, NA
12	Kamza 20	1994	AUT	L. Xhuveli, H. Sulovari	L, NA
13	30 Vjetori	1994	AUT	M.Përmeti, Xh. Shima	E, A
14	L.29.73	1994	AUT	M.Përmeti, Xh. Shima	L[e], A

15	Ni1448	1994		M. Përmeti	E, A
16	LVS 93	1999	ARIL	V. Malo	E, A
17	Drini	1999	AUT	L. Xhuveli, H. Sulovari	1/2E, A
18	Rinasi	1999	AUT	L. Xhuveli, H. Sulovari	1/2E, A
19	Ni 792	1999	BRI(c)	M. Përmeti, A. Kraja	L, A
20	Agimi x Nikla 486	2002	AUT		1/2E, NA
20	Progresi	2003	ARIL		½ E, A
*Triticum durum (*Desf)					
1	GR 28-74	1979	ARIL	M. Përmeti	E
2	Ç 178	1984	ARIL	M. Përmeti	L
3	Lushnja	1984	ARIL	S. Gozhita	E
4	Kamza D9	1984	AUT	L. Xhuveli, H. Sulovari, T. Sota	L
5	5/11-1	1990	ARIL	F. Kashta	E
6	(BI10 x 11C) X Ringo	1996	AUT	L. Xhuveli, H. Sulovari	E
7	Sota	1999	AUT	L. Xhuveli, H. Sulovari	1/2E
8	IKB-01	2003	ARIL		1/2E

AUT – Agricultural University of Tirana
ARIL – Agricultural Research Institute of Lushnja
BRI – Biological Research Institute
E – Early Maturity
L – Late Maturity
A – Awn
NA – No awn

During 1978-1985 the Plant Breeding Department of the Tirana Agricultural University, undertook an eight-year program of wheat breeding, based on backcrossing and mutagenesis. By combining sowing in open fields, with sowing in greenhouses during the off-season it was possible to select 2.6 generations per year (Fig 4 and 5). Using the backcrossing method the

"Line 35-77/4" (Albanian selection) as "donor parent" was crossed with Mexican variety "Indios" as "recurring parent". The variety "Indios" is known to have the desirable genes of early maturity and dwarfing genes for resistance to lodging. But at the same time "Indios" is not resistant to such diseases as fusarium head blight *(Fusarium graminearum)* and leaf blotch *(Septoria tritici)*. The genes of resistance of these diseases were possessing by the "donor parent" "Line 35-77/4". After four backcrossing, combined with accelerated seed multiplication, during the period 1978-1982, it was made possible to select 10 generations and thereby to create the new wheat variety with desirable characteristics named 'Kamza 16' (Xhuveli, 1984).

Figure 4: Accelerated multiplication of hybrid generations of the wheat in greenhouse conditions (Photo: August 1978).

Figure 5: Views of the accelerated multiplication of the wheat progenies in greenhouse conditions. (Photo: November 1981).

During the same period (1978-1985) a program using wheat mutagenesis was developed. Both durum wheat and bread wheat cultivars were included in this program. The radiation of the seeds with gamma rays released by Cobalt 60 was accomplished at the accelerator of the Institute of Nuclear Physics in Tirana. The greatest variation of the mutant generation was observed when dosages of 10-20 kr were used. Selection among mutant progenies produced a line of wheat that is up to 30% shorter than the parental plants. Through radiation of the Italian cultivar 'Libellula' a mutant line was created known as 'Fitorja 20 kr', with good adaptability in saline areas and high resistance to lodging. The mutant line 'Fitoria 20 kr' has a short stem and an increased width of the second node of the stem, as compared to the un-radiated cultivar. 'Libellula 20 kr' was used in a series of crossings as a parent and successfully transmitted such positive characteristics as resistance to lodging and high seed quality. This material is now part of the Albanian wheat collections (Xhuveli 1983, a; Xhuveli et al., 1983).

Wheat Breeding for Resistance to Lodging

Wheat lodging and associated losses have been among the most imported problems for wheat production in Albania. In some old indigenous wheat cultivars such as ‘Zhulica’, where the degree of lodging used to be high, losses were as high as 30% of the annual production. For this reason resistance to lodging became a main criterion for wheat breeding in Albania as well as for the introduction of new foreign cultivars.

Until 1970, Italian cultivars such as ‘Marzotto’, ‘Mara’, ‘Libellula’, and ‘San Pastore’, which possessed dwarfing genes transferred from the Japanese cultivar Akagomughi, were used as parents in breeding (D’Amato, 1989). After 1970 cultivars of Mexican origin, started to be introduced into the crossing program, which carried two important dwarfing genes from Norin 10, designated Rht-B1b and Rht-D1b (previously Rht1 and Rht2). A four-year study on approximately 900 bread wheat accessions for resistance to lodging identified a small part of promising entries (Xhuveli, 1979).

The most suitable parents for crossing were defined on these bases, and a model of wheat tolerant to lodging was developed. This model included the following characteristics: height of 80-90 cm, five nodes, height of the second node smaller that 9 cm and content of SiO_2 in the stem over 1.5% (Xhuveli, 1983, b).

The height of the stem has been used as one criterion for the selection process and the spreading of new wheat cultivars. Nowadays the height of wheat plants normally does not exceed 90 cm (Figure 5).

Figure 6: Changes in height of the stem in the most common cultivars for the period 1960- 1990. The name of cultivars starting from the left: Zhulica e bardhe; Mentana; Tevere; Tetori (San Pastore); Sukthi (Generoso); Myzeqea (Abbondanza); Lushnja (Strampelli); Dajti; L. 29-73; Agimi (Mec).

Breeding for Adaptability and Early Maturity

The identification of the best suited biological type of wheat for specific ecological regions (winter, spring, intermediate or facultative) has been a major topic of research, especially during the period 1970-1990. One of the outcomes of this research has been the identification of cultivars with early maturity, in order to avoid the negative effects of drought or high temperatures during the May-June period, when the crop is in its regenerative phase. Generally indigenous cultivars (wheat landraces) have been long cycle types with late maturity, which has limited their productivity.

Experiments during the period 1978-1981 determined the photoperiodic reaction of 887 bread wheat cultivars (Xhuveli, 1985). As a result wheat cultivars were classified into three types: spring, winter and intermediate. This classification will help in deciding parent's combinations for crossing. Studies during 1980-1982, based on reciprocal crosses, have shown that spring habit is dominant over the winter habit. The study also revealed the existence of the maternal inheritance of photo periodical reaction (Xhuveli, 1984). Winter and intermediate habit wheat types are the most adapted to the conditions of Albania. Spring habit types have proven to be unsuitable to the Albanian climatic conditions. For this reason spring habit cultivars have been abandoned and almost all cultivars sown in Albania during the last 20 years have been winter habit combined with early maturity.

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MEN AND PLANTS: A HISTORY INSCRIBED IN WORDS, DRAWINGS AND DNA

Domenico Pignone

Dedicated to my colleague and good friend Karl Hammer with whom I shared not only collecting missions, but also, and principally, many interesting discussions that kept us involved for hours.

"The history of the origin of human civilizations and agriculture is, of course, much older than the documentation in the form of pyramids, inscriptions and bas-reliefs or tombs can tell us. A close acquaintance with cultivated plants and with the multitude of types and their differentiation into geographical groups as well as their frequently sharp physiological isolation from each other compel us to refer the very origin of cultivated plants to such remote epochs, where periods of 5-10,000 years such as concern archeologists represent but a brief moment."

(N.I. Vavilov Origin and Geography of Cultivated Plants, 1987)

Abstract

At the end of the last glacial period, some 13,000 years before present, man made a discovery that radically changed the world: agriculture. This innovation led many things that we now take for granted: writing, culture, nations, technology and science. At the same time agriculture was the starting point of a new evolutionary force that through co-evolution of man and plants produced the many crops we know and use today. This epic history, made of trials and errors, of discoveries and disregards, is written not only in the DNA of these crops but also in books or paintings, and, in the oral tradition of many different populations or local communities. Until today, in isolated communities, it is often possible to find the tradition of cultivating a species unknown to the rest of the territory, or at least the remembrance of such activity.

The aim of this contribution is to demonstrate that an integrated approach to the study of genetic resources may disclose knowledge otherwise hidden, and that the attitude to produce new crops or varieties is not a prerogative of scientists alone, and even in present days, man holds the instinct to put new plants into cultivation.

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The Birth of Agriculture

The best of our knowledge on the passage from hunting-gathering to agriculture comes from the Middle East. At the end of the last glacial period man started the cultivation of *Triticum monococcum* and *Lens culinaris* (Salamini et al.2002, Sonnante et al. 2009). How did our progenitors discover that seeds of a species would regenerate plants of the same species is still obscure, and probably we will never know. Many hypotheses have been proposed: probably sites used as seed storage or as waste dumps might have beeb involved, triggering the idea of crop cultivation. What we know is that the passage was very quick (Table 1). In fact, it has been demonstrated that the size of a Neolithic villages grew in many few years and it has been hypothesized that this growth is due to the passage to agriculture, even though this vision is not accepted by all (Pringle 1998, Lev-Yadun et al.2000, Balter 2007). Of course, in the beginning, the seeds used for multiplication had been collected from the wild and cultivated as such. Following that pioneering period man learned how to select the propagation material from those plants showing most desirable traits. These traits could be quantitative, like those related to seed or fruit size, or qualitative ones such as reduced seed scattering or seed dormancy.

The history of the interaction between plants and man, is an impressive tale full of errors, starvation, death, discoveries, and power (Diamond 1997, Zohari and Hopf 2000), and it is written in many fragments of different nature. We have, until now, found only few of those pieces, which have taught us a lesson: none of these fragments alone, like the tiles of a mosaic, can illustrate the whole picture. We need all of them to learn about our past.

Table 1: The timeline of agriculture

Time	Archaeological evidence
20,000 ybp	Wild barley seeds at Ohalo II
12,000 ybp	Neolithic Revolution begins in the ancient Near East. Wild rye cultivated at Abu Hureyra I
11,000 ybp	Early farming sites in South East Turkey
10,000 ybp	Earliest evidence for domesticated wheat at Pre-Pottery Neolythic A sites at Abu Hureyra.
8,500 ybp	Pre-Pottery Neolythic B sites across the Fertile Crescent growing cereals and pulses (Abu Hureyra II).
7,000 ybp	Agricultural practices in southern Europe.
4,000 ybp	Egyptians discover bread making through the use of yeast
4,000 ybp	First use of light wooden ploughs in Mesopotamia
3,500 ybp	Irrigation being used in Mesopotamia

The Role of Gigantism and Mutations

The bigger the better. Bigger seeds or fruits were a better source of food, and our progenitors pursued this strategy in a very efficient way. A simple comparison between wild forms and old landraces of cultivated apples, eggplants or tomato will provide the necessary demonstration. This strategy is still one of the basis of modern day breeding.

In some cases the search for gigantic traits has produced striking results. One of these cases is the domesticated cardoon (*Cynara cardunculus* var. *altilis*). In this crop the domestication process has lead to gigantic leaf stalks which are the edible part of the plant. The difference with the wild progenitor (*C. cardunculus* var. *sylvestris*) is amazing: leaf stalk size grew of a factor of almost 10 (Hammer et al. 2006, Sonnante et al. 2007). Additional agricultural management techniques may further increase this size. The genetics of gigantism is often not completely determined, since many gigantic traits are under the control of a variety of quantitative trait loci (QTLs). The polygenic nature of these traits and the strong response to environmental factors do not easily allow a good genetic description (Bezant et al. 1997, Okogbenin and Fregene 2003). In fact, some QTLs are inconstant and are not identically espressed when growing the same genotype in different environments, or, conversely, not all genotypes of the same species express the same QTLs in the same environment. Furthermore, some QTLs appear to be epigenetically regulated, especially during plant development and ageing (Wu et al. 2002). The epigenes, that is the allelic variation due to differences in DNA methylation and not to DNA sequence change, have been proposed to have played an important role during plant evolution (Kalisz and Purugganan 2004), and therefore also in plant domestication, which, in the end, is a form of evolution guided by man (Peng et al. 2003). Modern approaches of comparative mapping are producing a better insight into this matter (Dirlewanger et al. 2004).

Mutations have been similarly important to plant domestication, and have been much earlier identified as associated to the domestication process. The complex of traits that distinguish the cultivated forms from the wild ones are described as the domestication syndrome (Hammer 1984, 2003). Many different mutations have been involved in the domestication syndrome of different crops, but some characters are recurrent in the same family, even though under the control of different genes (a recent reviewon this can be found in Dobley et al. 2006). In some cases the mutations involved, or better, causing domestication are strikingly evident, as in the case of the mutation leading to tough rachis in wheat. In *Triticum turgidum* this distinctive character between wild and domesticated emmer is controlled by two major genes, *brittle rachis 2* (*Br-A2*) and *brittle rachis 3* (*Br-A3*) which are located on the short arms of chromosomes 3A and 3B, respectively (Nalam et al. 2006). In the domestication of legumes, such as lentil, pea or grass pea, the first step triggering the domestication process was apparently due to single mutations in a major gene that prevented pod dehiscence (Ladizinsky 1979, Sonnante et al. 2009). These characters, due to their very clear effect on seed harvest, were easily positively selected by our progenitors, since they assued a better source of food.

Conversely, other mutations involved in the domestication syndrome are less obvious. For instance, those leading to a reduced seed dormancy, e.g. a reduced coat hardiness, are not easily perceived under normal agricultural conditions, since they are mimicked by other factors, such as reduced germination ability due to immature or non vital seeds. Probably the selection of such a character was totally serendipitous. In fact, seed dormancy is a character than can strongly affect plant production under agricultural conditions, and mutants produce a selective advantage for the genotypes carrying them. Although unconsciously selected, this has been one of the key factors in the domestication of many crops (Koinage et al. 1996, Cai and Morishima 2000, Sonnante et al. 2009).

Predomestication and Domestication

Domestication surely occued after cultivation. In fact the populations of hunter-gatherers first cultivated seeds taken from the wild and only in a second round they selected the most desirable genotypes (Hammer 1988, Pringle 1998, Balter 2007, Fuller 2007). How the cultivation idea was established is still obscure. Generally we tend to think that domestication is a definite process that has occurred in specific places and times, and that, nowadays, it is totally accomplished. However, many collection missions carried out in the latest years point to a different picture.

The author has carried out several collecting missions with Prof. Karl Hammer, within the frame of a collaborative programme started in the early 1980's (Hammer et al. 1987a, 1987b, 1994, 2008, Laghetti et al. 2008a, b, Perrino et al. 1992, Pignone 1990, 2007, Pignone et al. 1997, 2000). These collection missions allowed the author to visit areas in which agriculture was very marginal and carried out in a very traditional way. A distinctive trait of these areas was the strong relationship between the farmers and the plants they cultivated. It was impressive how farmers, generally elder people, were cultivating with much care and consciousness small family garden plots, called "*orti*" in Italian, where they stored traditional varieties of very minor crops, such as basil, parsley land, rocket, and where they experimented with "new" crops.

In several areas we found people cultivating plants that had been collected from the wild. In many occurrences it was possible to find small parcels of *Diplotaxis* sp., mostly for self consumption, far before an international collaborative project was started to produce a crop out of the wild species (Padulosi and Pignone 1997). The most interesting case regarded a farmer who was cultivating *Beta vulgaris* of the *maritima* type (wild form) in the Aspromonte mountains edges, a location far from the coast (Figure 1). Answering our questions, the farmer stated that he had collected wild beet seeds near the sea side and had planted them because the flavour of wild beet leaves was much more intense than that of the swiss chards, which he also cultivated for the local market as a cash crop. He also reported that, in former times, a leaf beet landrace was cultivated in that area, but it had disappeared. Even more interesting was the discovery that he also had a small parcel where he cultivated plants with an intermediate aspect between wild beet and swiss chard. The farmer said that the swiss chard plants had "fallen in love" with wild beets and he was trying selecting new plants with better flavour and reddish petioles (Figure 2). The farmer was almost illiterate but surely he was not ignorant!

Similar observations (Hammer *et al.*2008, Laghetti *et al*. 2008a, b) were made in the more rural areas of the islands of Crete, Lefkada, and Ithaca. There, farmers use to cultivate a form of *Amaranthus lividus*, locally called "*blito*". Together with this species, in several family gardens it was possible to find also *Amaranthus retroflexus*, a species considered to be only wild, and which grows abundantly all over Greece (Pignone et al. 2007). Nevertheless, many farmers stated that they also eat this wild form and do not remove *A. retroflexus* plants from their gardens, but simply select the bigger plants and use also their seeds for the next season. Should this process continue for some generations we will probably find new domesticates.

The many observations we made, the fact that traditional farmers (Figure 3) keep selecting new crops and new variants of the established ones to fit their needs or their taste and the conclusion that modern agricultural practices and political issues are profoundly changing the perception of agriculture in the younger generations (Pignone et al. 2000) have been at the basis of many stimulating discussions with Prof. Hammer. We have reached the conclusion that even in industrialised countries, where agriculture is mostly intensive and based on well established varieties, the domestication experiment has never reached its end, so that domestication can be defined as a "never ending story". Probably in human beings there are innate traits, like the curiosity for specific aspects of life aspects or the individual perception of life in its entireness, which, in the absence of cultural prejudice, are the forces pushing man to experiment with life and try change the environment to fit it to his own needs. In this respect we are not very different from the Neolithic hunter-gatherers who first experimented with agriculture.

Figure 1: cultivated plant of "wild beet" (Aspromonte, Italy 1986)

Figure 2: variation in leaf and petiole shape and colour in cultivated plants of "wild beet" (Aspromonte, Italy 1986)

Figure 3: primitive agricultural systems (Sardinia, Italy 1995)

The Power of Art: an integrated approach to study plant domestication

Until now we have considered the traces of the domestication process inscribed in the DNA of the domesticated plants. But there is also much useful information hidden in books. Latin authors like Pliny the Elder (1st Century AD, *Historia naturalis*) or Columella (1st Century AD, *De re rustica*), or even Greek comedies such as the comedy *Plutus* by Aristophanes 5th BC, are an incredible source of information on plants cultivated by the antiques, on their origin and specific aspects. The reading and the extraction of information from these books is made difficult by the fact that plants are referred to with common names, so the exact identification of the species may become difficult. We must not be surprised by this fact, nor think that the use of common names implies a non scientifically valid description. Even nowadays we can misinterpreter names: a swiss chard is not a Composita, nor is a Jerusalem artichoke a *Cynara* species at all. Even wider information is present in the less known Chinese (Willis 2008) and Arabic literature, which have been little translated into European languages. Only few examples are available (Peng 1984). For instance, recent publications based on the analysis of Chinese ancient literature shed a new light on the domestication of *Solanum melongena* (Dunay and Janik 2007, Wang et al. 2008). Also Arab literature suffers from the same problem of being little known to the wide audience of scientists, but, again, it contains a huge amount of useful information on crop domestication history (Idrisi 2005). Let us just remind the vast influence of the Arab domination of the Mediterranean (6th to 14th century AD) which led to the diffusion of many crops, eggplant in the first place.

Just to give an account of an integrated approach, making use of all the different sources available, to the study of crops origin, we might take in account two important Mediterranean crops: lentil and artichoke.

Lentil is one of the oldest crops, possibly sharing this position with *Triticum monococcum* (Lev-Yadun 2000, Salamini et al. 2002). Lentil has left many archaeological remains from Neolithic villages to Roman tombs. Its conography is not abundant, but this plant is amply described in books, spanning from agriculture to social life, since lentils were a staple food in the past and their importance decreased only after the domestication of other legumes (Sonnante et al. 2009). The importance of lentil is testified by citation in even religious books, such as the Bible. We have, therefore, much physical evidence of its domestication process. Genetic evidence is taken from general lentil genetics, mapping studies, and from the analysis of gene evolution (for a review, see Sonnante et al. 2009). Lentil has been studied even as a model to establish how fast was the passage from predomestication cultivation to the establishment of a fully domesticated crop.

Ladizinsky (1987) hypothesised that a selection for the absence of seed dormancy by means of repeated cycles of cultivation/selection of wild material could have lasted only one hundred years. But other authors refused this proposal (Zohary 1989, Blumer 1991).

It has been much more difficult to trace the history of artichoke domestication. In fact, opposite to lentil, the artichoke edible parts are fleshy and are not found in archaeological sites. Also the literature, although abundant, is not easy to interprete since the Romans ate a variety of Cardueae (*Scolymus*, *Silybum*, etc.) and also used different names for the same plant (see discussion above). Nevertheless genetic data based on ribosomal genes spacers and some historical records from the Arab times and medieval-renaissance period, have allowed a deep investigation of this issue. A key factor helping to date the domestication steps, came from the analysis of paintings, from Roman times mosaics to Italian Renaissance, to Flemish painters (Hammer et al. 2006, Sonnante et al. 2006, 2007). Artichoke and cardoon are often represented in still nature paintings and drawings, and in many cases the level of details allows a precise identification of domestication traits. Moreover, the converging evidence from DNA molecular evolution and from the origin and dating of the paintings, has allowed to clearly demonstrate that the place and time of domestication of artichoke and cardoon did not coincide (Hammer et al. 2006, Sonnante et al. 2007).

The analysis of other iconographic fonts may help in elucidating the domestication pathways of other crops. There are many books written at the end of the Middle Ages that illustrate crops with lots of particulars (e.g.: "*Tacuinum sanitatis in medicina*" also known as "*Libro di casa. Cerruti*" 14th century AD). These books not only tell us which species were cultivated, where and when, but also provide us with information about on their shape and appearance (Willerding 1992, Hammer, various lectures in 2008). And in some cases, they are a precise record of what was present at that time. For instance, the drawings of Leonardo da Vinci (1452 – 1519 AD), the famous Italian naturalist, considered as the prototype of the new humanistic man, are so rich in particulars that they may rival photographs.

Conclusions

Karl Hammer and I have spent much time together during collecting missions (Figure 4), during reciprocal visits at our respective laboratories, and even, giving lectures together. During this time spent together, the arguments of plant evolution and domestication have been the central topics of our chats. Karl's curious attitude and unprejudiced mind have let me discover aspects of the long lasting relationship between man and plants that no book had ever disclosed. Visiting very rural places his eyes often fell on "strange" forms that he suddenly recognised as the remnant of previous cultivations, or as feral forms, or as old relic forms of old landraces. The lesson I learned from Karl is that if we look at what surrounds us with the eyes of a curious child we can still learn much about how man has moulded wild plants into crops. And there is no place where this signs are absent.

Figure 4: collecting in ruderal areas (Sardinia, Italy 1995)

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From Neglect to Limelight: Issues, Methods and Approaches in Enhancing Sustainable Conservation and Use of Andean Grains in Bolivia and Peru

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Abstract

Quinoa (*Chenopodium quinoa* Willd.), cañihua (*C. pallidicaule* Aellen) and amaranth (*Amaranthus caudatus* L.) are staple crops for millions of people in the Andes (National Research Council 1989, Holle 1991, Jacobsen *et al.* 2003). Their nutritional content (high quality proteins and good micronutrient profile), hardiness, good adaptability to environmental stresses, versatility in use, and rich associated food culture and traditions are among the reasons for their widespread use by the native civilizations of the Andes over millennia. The role of these species as a staple food has however dramatically changed in the last fifteen years due to their poor economic competitiveness with commodity cereal crops, lack of improved varieties or enhanced cultivation practices, drudgery in processing and value addition, disorganized or non-existent market chains as well as a negative image as "food of the poor" (Querol 1988, Tapia *et al.* 1992, Padulosi *et al.* 2003). Less nutritious, but more practical and trendier products made of wheat, maize and rice have been replacing Andean grains in the diets of millions of people across Bolivia, Peru and Ecuador, countries whose history has been intimately linked to the domestication and use of these ancient crops (Pearsall 1992).

The reduced use of Andean grains has been accompanied by the loss of their genetic diversity with important, albeit less obvious, repercussions for the livelihoods of Andean communities in terms of reduced sustainability and resilience of local agricultural systems, wasted opportunities for improving food and nutrition security, impoverishment of local cultures resulting in reduced self esteem and identity of people (Bressani, 1993, Kraljevic 2006). As with minor millets in South Asia or leafy vegetables in sub-Saharan Africa (Oniang'o *et al.*, 2006), the case

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of Andean grains is representative of the limits of the Green Revolution approach, which concentrated its efforts on global commodity crops, missing out hundreds of other valuable species of regional or local importance and of great value to people's livelihoods (PADULOSI 2008).
The recognition that agricultural biodiversity is a strategic asset in people's lives has promoted over the last fifteen years or so, the rediscovery of those so-called neglected and underutilized species (NUS) crops which, as in the case of Andean grains, have for too long faced marginalization from the Research and Development sector, which has not supported their continued and effective use (PADULOSI and HOESCHLE-ZELEDON 2008). Several projects and collaborative research frameworks at national and international level have been launched in support of NUS, contributing to a re-focussing of needed and deserved attention on these 'forgotten crops'. To that end, an important role in demonstrating the value of NUS and the development of best practices, methodologies and tools for their use enhancement is being played by the 'IFAD-NUS Project', the first UN-supported global effort dedicated solely to the use enhancement of NUS, including quinoa, cañihua and amaranth, tackled through international participatory, multi-stakeholder and multi-disciplinary efforts.
This article reports on the work implemented by the project in Bolivia and Peru over the last seven years, highlighting significant approaches, experiences and outputs as well as challenges and experiences during the implementation of the project, which could be valuable lessons for other similar endeavors in support of NUS.

Key words:
Andean grains, genetic resources, conservation and use.

Introduction: NUS Definitions and Justification of Project

The definition of NUS has engaged scholars for some time now and we believe that the best way of sharing the common understanding of what NUS are is to indicate those traits that make these species (for better or for worse) distinct from other crops (Fig 1).

The conceptual framework for the promotion of NUS was developed by Bioversity International building on the results of more than ten years of work carried out around the world on these species (IPGRI, 2002). More recently a further elaboration of this framework was achieved through a number of conferences held with experts from Asia and Africa (JAENICKE and HOESCHLE-ZELEDON, 2006). Working on NUS entails a very different approach than working with well established crops. The use enhancement of NUS is challenged by many constraints, of which the following can be singled out as most recurrent: lack of information and scientific literature, lack of available germplasm and/or improved varieties, poor cultivation practices, poor value addition and marketing, lack of technical expertise and capacities in national programmes, and poor supportive policies (PADULOSI et al, 2002).

- **Important in local consumption and production systems:** they are an integral part of local culture, present in traditional food preparations and are the focus of current trends to revive culinary traditions;
- **Highly adapted to agro-ecological niches and marginal areas:** they have comparative advantages over commodity crops because they have been selected to withstand stressful conditions and can be cultivated using low input and biological techniques;
- **Ignored by policy makers and excluded from research and development agendas:** special efforts are needed to improve the cultivation, management, harvesting and post-harvesting of under-utilized species and studies are needed on issues such as marketability, nutritional status and policies and legal frameworks to regulate their use;
- **Represented by ecotypes or landraces:** most under-utilized species require some degree of improvement;
- **Cultivated and utilized drawing on indigenous knowledge:** cultivation and use can be enhanced by using farmer-based knowledge and by introducing innovative cultivation practices. Unfortunately, processes such as urbanisation and changing farming methods are contributing to the rapid erosion of traditional knowledge.
- **Hardly represented in *ex situ* gene banks:** efforts are needed to rescue and conserve genetic diversity of under-utilised species. Without characterization and evaluation the useful variation of these species will remain poorly understood. It is important to combine *ex-situ* with *in-situ* (on farm) conservation efforts as large-scale conservation efforts are unlikely to be made for these species. A “conservation through use” approach therefore becomes particularly important;
- **Characterized by fragile or non-existent seed supply systems:** efforts need to be made to provide planting material to farmers in order to make the cultivation of underutilized species more feasible and sustainable over time.

Fig. 1: Description of neglected and underutilized species (NUS) (from PADULOSI and HOESCHLE-ZELEDON 2004)

The IFAD NUS Project framework was developed through a series of multi-stakeholder workshops held in 2000 in Bolivia, Peru, Ecuador, India and Nepal. The Project was launched in 2001 and completed its first phase in 2005. Based on the outcome of an independent evaluation, a second three-year new phase was granted and launched in 2007 (PADULOSI, 2007).

With regard to the Bolivian and Peruvian components of the project, 34 project sites of between 20 to 120 families have been involved between phases I and II. All in all, more than 1,170 families have been directly involved in the implementation of the project, a fact that helps underscore the truly bottom-up, community-based and participatory approach of this project.

The global coordination of the Project is carried out by the international research organization Bioversity International based in Rome (Italy), while Fundación PROINPA, and CIRNMA are the two national agencies implementing the work in Bolivia and Peru respectively and coordinating activities undertaken jointly with a wide range of over twenty stakeholders from local NGOs and private enterprises such as food processing companies to universities, other research organizations and extension workers. The reach of the stakeholders covers expertise from grain production to ecotourism, nutritional analysis, conservation, marketing and food quality standard assurance.

Relevant approaches, methodologies, outputs and outcomes of the work carried out in these countries since 2001 are presented in this article grouped in the eight main areas of intervention as established in the project. Table 1 lists these domains along with the main activities pursued by the project to tackle the challenges faced in the areas of intervention.

Table 1: Problem areas, main foci and activities of the IFAD NUS project.

Area of Focus	Expected Outputs	Project Activities
1. Problem Area: Lack of the required genetic material of the target neglected and underutilized species		
Provision of genetic material of the target species	- Improved availability of seed and other planting materials - Crop improvement programmes - Improved planting materials for traditional varieties	- Set up local germplasm supply systems among rural communities - Initiate participatory improvement programmes to obtain clean planting materials and improved varieties
2. Problem Area: Loss of germplasm and traditional knowledge		
Conservation of germplasm and associated traditional knowledge	- Resource base of selected species secured through *ex situ* and on farm conservation - Appropriate traditional knowledge documented and shared among stakeholders	- Assess distribution of species and genetic erosion threats - Sample germplasm for *ex situ* maintenance and use - Implement on farm conservation through community-based actions

		- Identify and collate traditional knowledge using participatory procedures based on informed consent (including e.g. recipes on uses)
3. Problem Area: Lack of knowledge on uses, constraints and opportunities		
Documentation of knowledge on uses, constraints and opportunities	- Enhanced information on production levels, use constraints and opportunities - Knowledge of gender and other socially significant factors obtained	- Participatory surveys on uses, constraints and opportunities with communities and other levels of the production chain. - Analyze survey data for gender and other socially significant factors
4. Problem Area: Limited income generation		
Development of community-driven actions to enhance income generation	- Strategies for adding value and increasing rural incomes using target crops - Enhanced competitiveness of selected crops	- Develop value adding strategies (through processing, marketing, commercialization). - Investigate and identify improved agronomic and production procedures
5. Problem Area: Market, commercialization and demand limitations		
Actions addressing market, commercialization and demand limitations	- Enhanced working alliances among stakeholders in market chains - Improved processing and marketing opportunities identified - Improved capacities of marketing associations and producer groups	- Strengthen operational links in the market chain between seed supply system, processing and distribution stakeholders - Develop improved low-cost processing techniques - Analyze and identify market opportunities
6. Problem Area: Lack of research and development activities and weak national capacities		
Research and development-oriented activities to strengthen national capacities	- Enhanced national capacities to work with neglected and underutilized crops - Enhanced information and knowledge on the selected neglected and underutilized crops - Methods to improve nutritional values developed and documented	- Carry out short training courses for researchers - Develop and undertake community-based participatory courses - Characterize crops for agronomic, nutritional and market related traits - Study formal and informal classification systems - Investigate methods of maintaining and enhancing nutritional value - Investigate new areas of crop production

7. Problem Area: Lack of links across conservation and production to consumption value chains		
Establishment of effective links between conservation and crops value chains	- Market chains established or strengthened - Participatory networking procedures established	- Hold planning workshops for all stakeholders - Establish and strengthen operational links between stakeholders
8. Problem Area: Inappropriate or inadequate policy and legal frameworks		
Development of policy and legal frameworks and public awareness	- Raised awareness among policy-makers of issues and options for improved policy and legal frameworks - Links to existing rural and economic development projects enhanced	- Identify inappropriate policy/legal elements - Undertake public awareness actions among policy-makers - Establish close partnerships with extension workers and others involved in agricultural development

Material, Methods and Results

Area 1: Provision of genetic material to users

The lack of suitable varieties, or predominance of low yielding and /or pest and disease susceptible varieties is very often a major bottleneck hampering the promotion of NUS. With regard to Andean grains, earlier efforts made by PROINPA and CIRNMA on surveying, characterizing, assessing and selecting local material (INIA, 2002 and 2004; SOTO and PINTO, 2003; SOTO *et al.* , 2004) represented for the IFAD NUS project an important basis for launching its germplasm improvement efforts. Building on available local material and breeding lines, the project organized a number of participatory selection activities involving the three species. A total of 42 evaluation trials were carried out between 2001 and 2008 in both countries (20 in Bolivia and 22 in Peru). Criteria for selection used in these participatory trials included the identification of most useful market traits and indigenous knowledge on traditional uses reflecting also gender related criteria. Following are the results and observations emerging from these approaches.

Quinoa

An good example of the participatory work carried out with farmers in Bolivia was undertaken in the Regions of North and Central Altiplano during the 2002 season. In these trials, ten varieties originating from Bolivia were grown in eight demonstration plots. The results indicated that farmers preferred varieties mainly on the basis of yield, colour and seed size. However, the highest score assigned by farmers refered to yield rather than to the size of the grain. The varieties Chucapaca, Patacamaya, and Line 26 were selected as being the most attractive. Such a finding is somehow in contrast with the fact that the most popular variety in Bolivia and Peru today is "Quinoa Real", which is characterized by large, white grains. Because of the important role of Quinoa Real today in sustaining the incomes of farmers in Bolivia and Peru, the project directed some research efforts to also understand better the variation within the variety with the objective of broadening the number of ecotypes that could be used by farmers in the cultivation of this type of quinoa. Trials to assess the agro-morphological characteristics and yield of six Quinoa Real ecotypes (Achachino, Lipeña, Toledo, Pandela, Kellu and Pisankalla) were carried out in Chacala in the Southern Altiplano region of Bolivia in the summer of 2002-2003. The trials revealed that all ecotypes were characterized by branching, short branches, and great variation with regard to plant colour, physiological maturity dates and colour of grain before threshing (Table 2). For all grains with the exception of Pisankalla the colour after saponin removal is white. The average height of the plants ranged from 70.2 cm (Kellu) to 87.0 cm (Toledo); the length of the panicle ranged from 20.3 cm (Pandela) to 28.1 cm (Lipeña); and the yield ranged from 644 kg/ha (Pandela) to 915 kg/ha (Kellu) (Table 2). The low yields obtained in these trials were greatly influenced by drought during this growing season in Bolivia.

In Peru, the participatory selections on quinoa made in three districts of Puno led to the identification of nine promising ecotypes. Resistance was seen as a fundamental trait by farmers; the "Koitu" variety was selected for its resistance to cold and frosts and its resistance to the main pest *Eurysacca quinoae* ("k'ona k'ona" in Quechua language) and the variety group "Witullas" is characterized by resistance to cold (particularly the "Orqo Witulla" ecotype), drought and pests. Farmers believe that white seed quinoa varieties are more susceptible to abiotic stresses than those of other seed colours (although characterized by good grain yield, which might explain the preference in Bolivia for white grains). In the end, these evaluations resulted in the identification of the early maturing ecotypes of Witullas, Sajama, Quello Juira, Janco-quello and Yoqello and the late maturing ecotypes of Kuchiwila, Chullpi and Pasankalla. The Chullpi ecotype showed the highest yield (3,600 kg/ha) followed by white grain quinoa (3,000 kg/ha), and pinkish grain quinoa Witullas (2,200 kg/ha).

Table 2: Agro-morphological traits and production traits in Quinoa Real ecotypes characterized in Chacala, Bolivia in the summer of 2002-2003.

Ecotypes	Growth habit	Seed colour at maturity	Panicle shape	Seed colour after saponin removal	Size of grain (mm)	Cultivated area (m2)	Height of plant (cm)	Length of panicle (cm)	Yield (Kg/ha)
Kellu	Branching	Orange-like	Amaranth-like	White	2.57	1005	70.2	21.3	915
Lipeña	Branching	Light cream	Amaranth	White	2.35	3680	72.6	28.1	750
Toledo	Branching	Orange-reddish	Amaranth	White	2.45	1780	87.0	25.6	775
Achachino	Branching	Red	Amaranth	White	2.17	3200	77.7	23.4	862
Pandela	Branching	Pinkish	Amaranth	White	2.2	5500	73.3	20.3	644
Pisankalla	Branching	Purple	Glomerule-like	Coffee colour	2.4	5280	76.7	26.0	736

Cañihua

Based on a preliminary evaluation of cañihua germplasm carried out in Bolivia in 2002 by PROINPA, the most promising varieties with interesting grain and yield traits were used in the 2002-2006 seasons for a participatory evaluation involving thirteen communities from the departments of La Paz, Oruro and Cochabamba in the regions of the Altiplano Norte, Altiplano Centro and Zona Alta respectively.

The results of these trials were used for the selection of accessions No. 081 and 472, appreciated by farmers for their precocity, homogeneity and high yield, whitish colour of the flower bracts and large brown grains. These accessions were deployed by the National Seed Programme of Bolivia for the selection of two commercial varieties successfully released in 2007 with the names of "Illimani" and "Kullaca" (Fig 2), which represented the very first cañihua varieties to have been released in this country.

Fig. 2: Characteristics of "Illimani" and "Kullaca" cañihua varieties released in Bolivia in 2007.

ILLIMANI

Plant colour: green at flowering and pinkish-orange at maturity
Colour of inflorescence: whitish
Plant height: 54 cm (average)
Days to maturity: 160
Potential grain yield: 1500 to 2000 kg/ha
Yield average: 800 kg/ha
Grain colour (with perigonium): greyish-white
Grain colour (without perigonium): dark coffee
Grain diameter: 1.20 mm

KULLACA

Plant colour: Green at flowering and purple at maturity
Colour of inflorescence: whitish
Plant height: 50 cm (average)
Days to maturity: 150
Potential yield: 1000 to 1200 kg/ha
Yield average: 700 kg/ha
Grain colour (with perigonium): greyish-white (see left, top)
Grain colour (without perigonium): dark coffee (see left, bottom)
Diameter: 1.22 mm

In Peru, cañihua is cultivated with good yields at lower altitudes on black soils. The crop is resistant to cold temperatures and hail (TAPIA *et al.*, 1979). It has a much shorter habit than quinoa, fewer ramifications, pinkish stems and green leaves. In this country the participatory selection trials were carried out during the 2002-2003 and 2003-2004 seasons at Illpa, Chullunquiani and Camacani (located in the Puno region of the country). Sixteen lines obtained from the INIA gene bank in Puno were used for the trials. The results of the trials indicated that accession. 419 had the highest performance at all the three sites (421.39 g/4m^2), followed by accession 100 (413.90 g/4m^2). Six accessions had a good response to favourable environments (accessions 100, 181, 354, 419, 422 and M2), whereas accessions 212 and 405 were found important for acceptable performance in unfavourable environments (or those characterized by low technology and in general used for self-consumption farming systems). In order to make the use of gene bank material more efficient and cost effective, a study was also conducted on the cañihua germplasm maintained at the UNA Puno gene bank in Peru aimed at the identification of duplicate accessions: 96 duplicates (out of 374 accessions of cañihua collected in 2002) were identified through these investigations.

Amaranth

In Bolivia, during the 2002-2003 seasons, some 100 amaranth accessions were evaluated in the communities of Sauces (Gerardo Pozo District), Chirimolle Pampa (Alberto Montaño District), Tipa K'asa (Félix Rosas District) and Molleaguada Alta (Leandro Sejas District). The agro-morphological traits used in these evaluations included early flowering, height of plant at flowering stage, dehiscence of seed, grain yield per plant, lodging at plant maturity, position of panicles within the plant and percentage of expansion of seeds (for the production of popped grains – a top priority market trait). The results indicated that white and semi-white seeds had greatest performance with regard to this important market quality trait (and were characterized at the same time also by early maturing trait). Accessions of amaranth with crystal endosperms, on the other hand, were characterized by the highest plant growth and dehiscence in the panicles.

In Peru, the participatory selection of amaranth focused on Calca Province and was carried out at the experimental fields of INIA in collaboration with the local "Amaranth Producers Association" involving many farmer workshops organized to identify the best criteria for the selection of germplasm. Interesting differences emerged between male and female farmers (Fig 3).

Table 3: Selection criteria for amaranth in participatory evaluation carried out in Cuzco, Peru.

Priority traits selected by men	Priority traits selected by women	Common traits to both groups
• Erect panicle • Panicle with large size • Early maturing • Resistant to diseases • Easy harvest • White grain • Not dehiscent • Good production	• Erect panicle • Panicle with large size • White grain • Thick stalks • Early maturing • Resistant to disease and / or pests • Easy harvest • Tall plants • Large leaves	• Plants with large, erect panicle • White grains • Early maturing (for cultivation in • rainfall cultivations) • Resistant to disease and / or pests • Good production

The result of these participatory evaluations led to the selection of six most promising ecotypes out of which Taray 412, was successfully released by INIA in 2008 (Fig 4).

Table 4: Agronomic characteristics of the amaranth variety Taray 412 released by INIA in 2007 in Peru.

Growing habit	Erect
Plant height at flowering	150 cm
Thorns at the base of the petiole	absent
Apical inflorescence shape	Ear-shaped
Apical inflorescence position	Erect
Inflorescence density index	Dense
Inflorescence colour	Red
Grain colour	Light yellow
Grain shape	Round
Days to flowering	120
Grain loss in the field	Medium (20%)
Seed yield per plant	300 - 700 g
Thousand seed weight	1.10 g
Potential yield	3500 kg/ha
Farmer's yield (average)	2500 kg/ha
Lodging at maturity	Low
Seed emergence rate	97%
Days to maturity	170

The data gathered during the participatory selection trials was very useful for identifying varieties with traits of interest for farmers in Bolivia and Peru. As a whole, some six varieties of quinoa, amaranth and cañihua were selected and distributed to farmers by the project. However, more selection work is needed to meet local farmers' emerging needs including selection of varieties to address climate change phenomena. During the implementation of the project in fact, both in Bolivia and Peru, farmers reported increased occurrence of droughts, changes in temperature (more instances of cold spells and/or higher temperatures) during the planting season which led them to shift the planting dates of the target crops considerably as an impact mitigating measure. The selection of germplasm better adapted to these changes, and investigation into the potential impact of new material in the use of Andean grains in the coming years are thus important fields for further research. The multiplication of the accessions and varieties selected during the trials was done as a collaboration between the PROINPA Foundation, the Fito-ecogenetics Research Centre (CIFP), and the Faculty of Agronomy of The Major University of San Andres (UMSA) (Bolivia), three producers' associations of quinoa and cañihua (Cabana and Lampa) and one amaranth association (Curahuasi in Cusco) in Peru. More than six tonnes of seed were obtained by these efforts from twelve varieties in Bolivia and six in Peru. More than twenty demonstration plots were established to promote the use of the selected material by farmers at the pilot sites of the project in Bolivia and Peru from 2001 till 2008.

Another important activity was the assessment of the genetic diversity of target crops in farmers' fields. The area chosen for these studies was Lake Titicaca (one of the largest and highest lakes in the world located at 3,835 masl), whose surroundings are considered to be the most important centre of diversity for quinoa and cañihua (TAPIA, 1992). During the Inca Empire, these crops were very popular, particularly during the Tiahuanaco Period, but following Spanish colonization they were gradually displaced and substituted with maize and wheat, a process that has continued until today to the extent that their genetic diversity has been severely eroded (ROJAS, 2003). In order to gain a better understanding of the current status of both genetic diversity and genetic erosion the project carried out a survey in this area involving more than 467 families across five provinces of the department of La Paz. The results of the survey indicated that the diversity of quinoa and cañihua is affected by severe genetic erosion, thus confirming earlier reports (ROJAS *et al.* 2003, and 2004). It is interesting to note that whenever the farmers interviewed were asked about crop preferences, they always indicated quinoa and cañihua among their top choices (usually following potato, faba bean and/or oca *Oxalis tuberosa*). The survey revealed that only 40 local varieties of quinoa and 20 of cañihua were being cultivated today out of at least 200 estimated to be have been cultivated there in the past and that the average family was growing only one to four varieties of these crops in its fields (85% cultivated only a single variety). The most preferred variety of quinoa (var. 'Janko Jupa') was cultivated by 32% of the families. In order to contribute to halting this dramatic genetic erosion and in view of the important role that this area plays in the *in situ* conservation of Andean grains and their associated traditions, the project intervened with some targeted efforts: most threatened varieties were identified, multiplied and their seed distributed among local communities around Lake Titicaca for reintroduction. As a whole, some 120 kg of 40 varieties obtained from the *ex situ* gene bank of PROINPA and CIRNMA were provided by the project from 2001 to 2008. The restitution of lost varieties to their original areas of cultivation demonstrated the important role that *ex* *situ* conservation plays in the safeguarding of agricultural biodiversity. In view of the very limited representation of NUS crops in the 1,300 gene banks around the world, the role of farmers as custodians of NUS diversity and the need for greater support for their work cannot be over emphasized (PADULOSI *et al.*, 2002).

Area 2: Conservation of germplasm and associated traditional knowledge

According to a preliminary calculation, we can estimate that the genetic diversity of Andean grains has been collected in Bolivia for 70% and in Peru for 45% of the estimated area of their total distribution. In its efforts to sample the genetic diversity of these species, the IFAD NUS project adopted a gap filling approach, strategically sampling only those areas where genetic diversity was considered to be highest and/or areas where genetic erosion were also registered. Fig 5 shows the sites of cultivation and collection of cañihua in Peru carried out by the project since 2002.

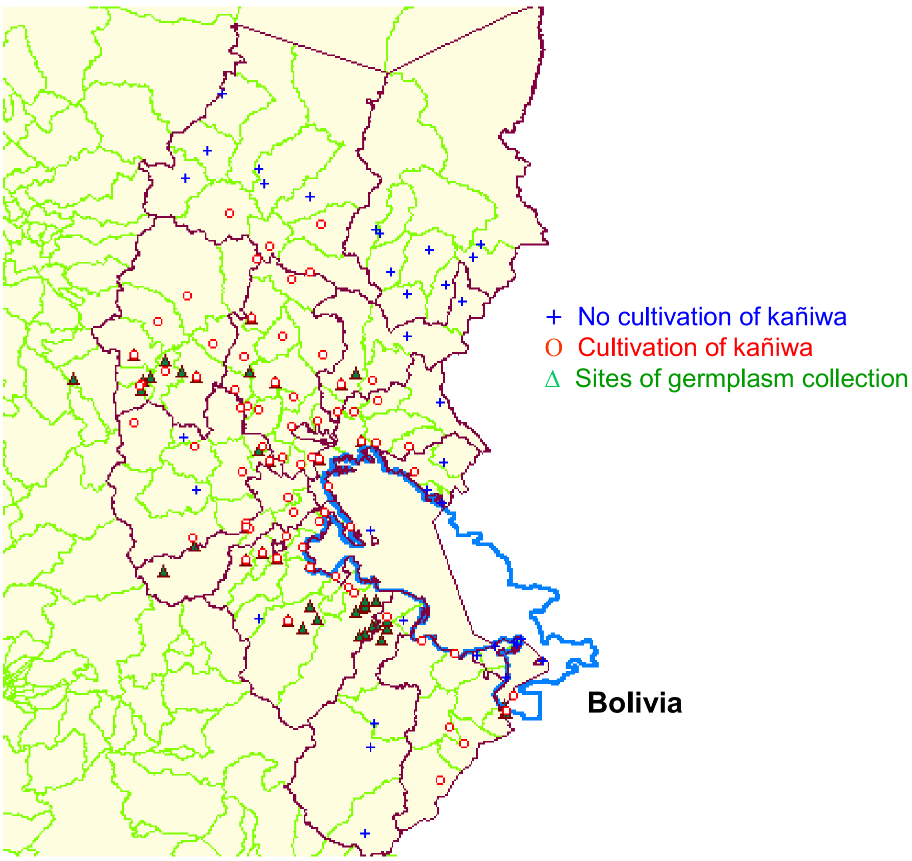

Fig. 5: Areas of distribution and collecting sites of cañihua in Peru (CATACORA 2002).

Nine missions (six in Bolivia and three in Peru) were launched as a whole from 2001 to 2004 and 1492 samples of Andean grains were gathered (Table 3).

Table 3: Andean grain germplasm collected in Bolivia and Peru from 2002 to 2004 in the framework of the IFAD-NUS project.

Country	Quinoa	Canihua	Amaranth	Total
Bolivia	144	406	136	686
Peru	145	586	65	796
Total	289	992	201	1492

In addition to the collection of new germplasm, the project also supported the recovery of many accessions in gene banks, through viability tests and regeneration activities. In Bolivia alone, these efforts contributed to an ultimate increase of quinoa, cañihua and amaranth germplasm in gene banks estimated at between 30 and 100% (ROJAS *et al.*, 2003).

In order to assist researchers and other workers in their studies aimed at assessing and enhancing the use of the genetic diversity of quinoa maintained in gene banks, a germplasm catalogue for quinoa about the accessions at the PROINPA gene bank in La Paz, Bolivia was developed and widely disseminated in hard and soft copies (ROJAS *et al.*, 2001). A catalogue on the material of quinoa, cañihua and amaranth collected in Peru along with passport data was also developed (CIRNMA, 2007). The first cañihua descriptor list was produced and published within the Bioversity series of Crop Descriptors (IPGRI, 2005). Visits by farmers to gene banks were also organized to promote the much needed linkages between conservationists and user communities, often indicated as a major obstacle in promoting the use of agrobiodiversity (FAO 1996).

During the amaranth collecting missions carried out by INIA-Cusco and AEDES in Cusco, Arequipa and Apurimac in Peru, a low presence of genetic diversity was observed and most worry some more than 80% of the area cultivated with amaranth was observed to be cultivated with only one variety (Oscar Blanco).

The data gathered during the multiplication of the germplasm collected in Peru by the project and carried out at the UNA and INIA gene banks, showed that among the quinoa germplasm, green, pinkish and purple seeds were the most common types The most common inflorescence type is the glomerule-like one, 21 accessions had amaranth-like inflorescences, and 135 were of the intermediate type. The study revealed also the presence of 91 accessions tolerant to frost.

The project decided to upgrade important collections of Andean grains which needed urgent attention. The infrastructure and conservation capacities of a number of gene banks were therefore improved: the National Andean Grains Gene Bank at the PROINPA Foundation in La Paz (Bolivia), The Fito-ecogenetics Research Centre (CIFP) Gene Bank of Pairumani (Bolivia), the Gene Bank of the National Altiplano University of Camacani (Peru) and the Gene Bank of the Experimental Station of the National Institute of Agricultural Research and Extension (INIEA) of Illpa (Peru). The interventions benefitted more than 7,000 accessions maintained in these collections. The multiplication of 536 accessions of quinoa maintained at the Illpa gene bank was also supported, which allowed the regeneration, and characterization of valuable material along with their characterization for agronomic traits.

In order to assist Andean grain breeders and their user community at large, the IFAD NUS project carried out *ad hoc* studies for the establishment of core collections for quinoa, cañihua and amaranth, (HODGKIN *et al.* 1995). These core collections, particularly of quinoa, have contributed to an increase in the use of genetic material from the crop genetic improvement programme, where researchers are working on the identification and selection of promising varieties of quinoa to address abiotic stresses such as frost and drought but also to search for specific economically important market traits. The quinoa core collection was developed based on a matrix of data on 2,514 germplasm accessions and 18 quantitative variables, using correlation coefficient and multivariate analysis methods (DILLON and GOLDSTEIN, 1984; PLA, 1986; HAIR *et al.*, 1992). This study led to the identification of six different groups (Fig 6) from which 267 representative accessions were selected to form the core collection: 200 accessions originated from Bolivia (the major contribution of material originated in La Paz, Oruro and Potosí), 48 accessions from Peru (significant contribution from Puno), 6 accessions from North Argentina, 1 accession from Ecuador and 1 accession from Europe (introduced material). For eleven accessions passport data were not available. The 267 accessions selected represent 10.6% of the whole germplasm collection characterized by PROINPA.

Similar studies carried out for cañihua (499 accessions and 20 variables) led to the identification of 4 main groups of accessions (Fig. 7) from which 57 accessions were selected to form the core collection (39 from Bolivia (all but one accession from La Paz), 1 from Peru (Puno) and 17 of unknown origin), representing 11.4% of the characterized PROINPA collection of cañihua. The development of the amaranth core collection based on 221 accessions and 12 quantitative variables led to the identification of 2 groups (16 accessions in group 1 and 7 accessions in group 2) and the development of a core collection of 23 accessions (10.4% of the total collection of characterized amaranth available at CIFP).

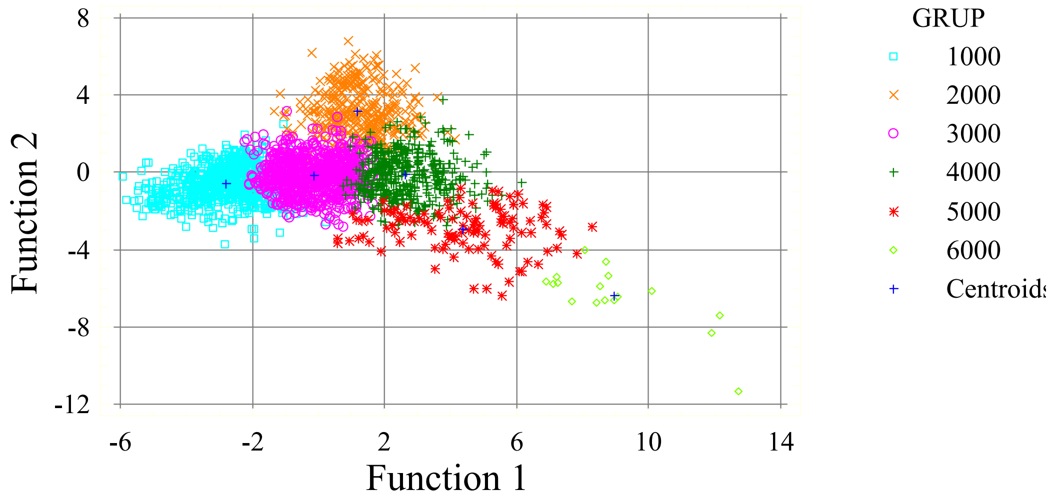

Fig. 6: **Spatial distribution of the six groups of quinoa identified in its core collection developed by PROINPA**

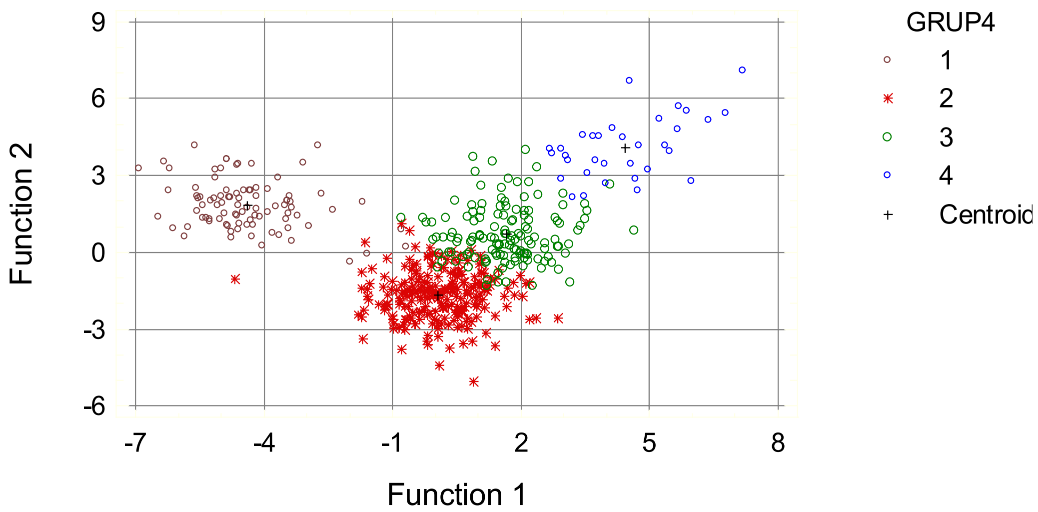

Fig. 7: **Spatial distribution of the four groups identified in the core cañihua collection developed by PROINPA**

The loss of indigenous knowledge (IK) about Andean crops is a widespread phenomenon of great concern in view of the important role that it plays in maintaining traditions of cultivation and use. The recuperation of IK was addressed by the IFAD NUS Project through a number of surveys at the community level in the project sites. During these participatory data gathering activities, detailed information was collected from local farmers with regard to traditional cultivations methods in the 'aynoqas' (community lands), 'sayañas' (lands around farmers' houses), 'kjochi irana' (lands near Lake Titicaca) and 'uyus' (corrals). Important data regarding biological indicators still used by farmers in traditional systems of cultivation land, valuable for assessing the level of conservation of quinoa, cañihua and amaranth were also gathered.

The project focused also on *in situ* conservation, in consideration of the contribution played by local communities in safeguarding genetic diversity on their farms, efforts which are highly complementary in nature to those made through *ex situ* approaches. An important contribution to the on-farm conservation of Andean grains in Bolivia and Peru is made by women. One example is the case of Ms Petronila Neyra from Puno (Peru), a farmer who safeguards on her farm more than 55 accessions of quinoa. Her contribution and that of many other custodians of genetic resources of Andean Grains were publicly recognized during more than 21 Biodiversity Fairs organized by the project in Bolivia and Peru (and Ecuador) from 2002 till 2008. Among these, noteworthy of mention were the first Fairs ever organized for quinoa and amaranth in Bolivia. These fairs represent an important instrument to promote the sharing of material and information about local crops among farmers and other users and value chain actors. Information shared during the fairs includes data on ethnobotanic uses, agronomic characteristics, commercialization and transformation, which is valuable for the promotion of agrobiodiversity, and NUS in particular (CIRNMA, 2004; FAO, 2006). Fairs play an important role in keeping alive the traditions and culture of NUS, under threat of erosion due to globalization and other social trends. They also represent a valuable instrument for the conservation of local varieties by promoting exchange in an informal way. During these fairs many ecotypes of target crops were identified and samples were taken for conservation measures in *ex situ* gene banks. As an example, more than 39 ecotypes of cañihua, were sampled during the fairs organized by IFAD NUS in Peru from 2002 to 2008. Furthermore, during the seed fairs organized in Arequipa and Curahuasi (also in Peru), the project was able to identify 30 accessions of amaranth (*Amarantus caudatus*) of which at least four were said to be under severe threat of genetic erosion. In order to make the fairs a self-sustainable event beyond the life of the project, efforts were made towards their institutionalization and adoption by national and local agencies. This is the case of the "Biodiversity and Popular Andean Art Fair" which will be now held annually on June 20th and 21st at the Tiwanaku Municipality, as part of the "Aymara New Year" Celebrations, and which will receive continued support from the Ministry of Culture and Development, the Ministry of Tourism and other important agencies in Bolivia. In Peru, similar efforts have led to the institutionalization of the "Cabanillas' Agrobiodiversity Fair" which is held every September in the city of Cabanillas (Puno District) in collaboration with the local Municipality, the Ministry of Agriculture, the IFAD Puno-Cuzco Corridor and other development and rural organizations. In Peru from 2001 to 2008 some 14 diversity fairs were organized by the project, with the involvement of more than 540 families from local communities.

Area 3: Documentation of knowledge on uses, constraints and opportunities

As already mentioned in the previous section, IK on uses of target crops was gathered during the biodiversity and seed fairs, germplasm collecting expeditions, and *ad hoc* socio-economic surveys carried out along the production to consumption chains of target crops. An example of the work carried out in this domain is the survey on the management of traditional food systems of quinoa, cañihua and amaranth crops in the north high plateau (Altiplano) and high valleys of Bolivia, and in the high plateau of the Department of Puno in Peru. In these communities, research was carried out regarding traditional uses of target crops, which allowed the recovery of traditional knowledge on cultivation practices, management, food culture and constraints associated with these practices. Data were gathered about food traditions, indicating a great diversity of food preparations, whose recipes are safeguarded particularly by the elder members of the community. Examples of these local recipes using Andean grains as ingredients are the K'ispiña (steam-cooked quinoa biscuits), pito (ground and toasted grains), tayach'a (k'ispiña of cañihua prepared with milk and frozen), pesq'e (boiled quinoa with milk and cheese), soups and stews (ALCOCER, 2003; ARONI *et al.* 2003). The project gathered and documented existing recipes for preparing Andean grains and also developed novel recipes in a participatory manner through discussions and focus groups with local women. Grains of quinoa, cañihua and amaranth are used for both human and animal consumption, and also for medicinal and religious purposes.

Area 4: Development of community-driven actions to enhance income generation

The lack of competitiveness in the market is perhaps the most common constraint in the promotion of NUS. This aspect is rather complex and involves interventions in many directions such as identification of agronomic obstacles hindering effective cultivation and harvest, post harvest limitations, value addition bottlenecks, and constraints in the organization of the market chain. According to the participatory workshops held with stakeholders, the main obstacles to the use of Andean grains are to be found in post harvest and value addition domains. For that reason, special attention was devoted to the development of technological solutions aimed at improving threshing and saponin removal operations. In Bolivia two prototype threshing machines for quinoa were designed, built and validated by community members. Results show that operation is optimal, with a performance of 95 kg/h of threshed grain, compared to 100 kg/day as achieved by a farmer manually. These prototypes respond to farmers' demand for lower levels of contamination by stones and grit, reduced loss of grain, suitability for small and medium operations, and easily transported field equipment at accessible prices (PACOSILLO, 2003; QUISPE, 2004).

Another area of improvement which was tackled by the project is the de-saponification of quinoa grains. Saponin is an alkaloid present in quinoa (absent in cañihua and amaranth). While saponin plays an important role in conferring pest resistance to quinoa varieties (JACOBSEN *et al.*, 2000), it is in fact an anti-nutritional substance and needs to be removed from the seeds to allow human consumption. The removal of saponin has been traditionally done by women, who spend at least six hours daily task (ASTUDILLO, in press). In addition to the drudgery and time involved, there is also the hazard of inhalation of the saponin dust which may damage the eyes and respiratory tracts. A machine for saponin removal was manufactured by the project and several specimens were handed to families in the city of Uyuni (Central Altiplano), where the project had found a decrease of the use of quinoa and a reduction in the genetic diversity used by people reportedly because of the drudgery of the saponin removal process. Monitoring of the use of the machines by the communities to assess the impact in enhancing the use of highly nutritious quinoa varieties in that area (affected by malnutrition) and its expected positive impact on the conservation of local varieties was very encouraging trend in few months (Table 4)

Table 4: Number of families using the saponin removing machine produced by the project and number/types of culinary uses (December 2007 to March 2008 period).

No.	Community	No. families	Amount of grains processed per culinary use (kg)					Total (kg)
			Soup	'Phisara'	'Pito'	'Mucuna'	Flour	
1	Copacabana	22	70.31	36.29	36.29	0	13.61	156.50
2	Colcha K	12	127.01	54.43	0	0	0	181.44
3	Jirira	8	22.68	11.34	11.34	22.68	22.68	90.72
4	Irpani	15	252.20	179.17	466.29	239.04	419.12	1555.82
5	Chita	14	206.38	246.30	204.12	149.69	48.53	855.02
Total		71	678.58	527.53	718.04	411.41	503.94	2839.5

Area 5: Actions addressing markets, commercialization and demand limitations

The main factor limiting the sale of these grains appears to be the quality of the product offered for sale. Today, Andean grains have very good commercial opportunities, since there is high demand in local markets that has not yet been satisfied (BENAVIDEZ, 2003; MAMANI and CHUGAR, 2003; MAMANI and Yana, 2003).

During the first phase of the project it became clear that greater investment in research was needed to reinforce the promotion of local varieties. This approach in raising demand was developed in the second phase of the project following three main lines of intervention: 1) assess the nutritional content of landraces (in raw as well as processed material) of target crops, 2) develop more attractive products, particularly for younger people and 3) carry out campaigns to promote target crops and their nutritious products. An example of the type of investigations being carried out on cañihua by the project to assess the nutritional profile of different varieties in raw and processed products is provided in Table 5.

The project is further investigating through an extensive study (collation of data and new analyses both in Bolivia and Peru) the nutritional diversity present in quinoa, cañihua and amaranth germplasm, (Table 6).

Table 5: Chemical and functional composition of different varieties of cañihua in grains, flour, cakes and desserts carried out in Peru (from GUTIERREZ, 2002).

Parameter	Var. 'Cupi' (seed) %	Var. 'Cupi' (flour) %	Var. 'Ramis' (seed) %	Var. 'Ramis' (flour) %	Cakes (g / 100g of food)	Dessert (g / 100g of food)
Protein	15.19	15.19	16.6	14.73	3.5	8.0
Water	12.25	5.22	7.94	5.30	--	--
Ashes	2.42	2.42	2.61	2.27	--	--
Fat	8.80	7.82	7.30	8.01	3.86	6.7
Carbohydrates	56.6	61.03	57.30	61.38	36.4	28.0
Fiber	9.86	8.18	8.47	8.41	--	--
Fe (mg)	--	--	--	--	2.36	8.9
Kcal	--	--	--	--	193.7	220.18

Amino acid content in 100g of proteins						
Isoleucin	--	--	--	--	1.58	1.91
Leucin	--	--	--	--	0.69	1.23
Lysin	--	--	--	--	0.84	1.16
Metionin	--	--	--	--	0.75	1.32
Phenylalanina +Tyrosin	--	--	--	--	0.46	1.20
Treonin	--	--	--	--	1.156	1.36
Tryptophan	--	--	--	--	0.90	1.21
Valin	--	--	--	--	1.024	1.80
Histidin	--	--	--	--	1.14	1.43
Digestibility (%)	--	--	--	--	93.24	95.63

Table 6: Nutritional properties in leaves and toasted grains of amaranth in Peru.

Parameter	Fresh leaves	Dry leaves	Toasted grains
Water (%)	85.56	--	1.14
Protein (%)	3.42	23.68	17.12
Ash (%)	2.73	18.91	2.42
Fat (%)	0.11	0.76	7.41
Fiber (%)	14.82	14.82	3.61
Carbohydrates (%)	6.04	41.83	68.30
Energy (Kcal/100g)	30.83	213.50	409.67
P (mg/100 g)	--	--	537.5
Ca (mg/100 g)	--	--	127.35
Fe (mg/100 g)	--	--	11.46

Investigations in Quinoa Real, initiated in the fields of Chacala in the Altiplano Sur region of Bolivia (see section 2 on quinoa), continued in the laboratory of LA&SAA (Análisis y Servicio de Asesoramiento en Alimentos) in Cochabamba, Bolivia. The aim was to determine the potential for transformation of each of these currently marginalized ecotypes of Quinoa

Real. The results of the laboratory analyses indicated that the ecotype Achachino is characterized by an exceptional nutrition profile (protein 18.29%, fat 3.11% and fiber 6.28%). Achachino also showed good properties for the preparation of pasta (followed by Kellu and Pandela ecotypes). The analysis of sugar indicated that the ecotypes Pandela and Toledo are best for bread-making and also have an ideal sugar content for the preparation of juices. With regard to the preparation of biscuits, measurements of starch grains indicated that Pisankalla had the best texture for these products as its starch grains were the smallest (0.004 mm) of all (grains characterized by diameter ranging from 2.17 to 2.57 mm). According to the Bolivian regulation "Cereals - quinoa grain - classification and requirements"[1], the grains of quinoa are classified as follows: 1) extra-large (size 2.2 mm and beyond), 2) grains of prime class (1.75-2.2 mm in diameter). These ecotypes would therefore fall easily into the good quality categories. The laboratory analyses revealed the highest protein content is in Achachino (18.29%) and the lowest in Pandela (13.34%). The fiber content was highest in Lipeña (9.11%), which is an interesting result in view of the important role that fiber plays in the diets of people affected by cardiovascular disease, diabetes and obesity.

Greater consumption at the family level (particularly among children) is being promoted by the project through novel and more attractive recipes for cookies, cakes, juices and other products. Collaboration with the private sector is already resulting in the development of nougat, muesli, drinks and other commercially viable products for the three crops. In Bolivia, participatory culinary aptitude tests were organized to test biscuits and cakes prepared with quinoa, cañihua and amaranth, including a variety of juices made of these grains combined with fruits. Recipes for promoting these uses at family level have been published and disseminated (ALCOCER, 2003; ARONI *et al.*, 2003). At an industrial level quinoa flakes, noodles, popped quinoa and cañihua and fine flour have been elaborated. Amaranth energy bars with honey were obtained, as well as granola with oats, almonds, peanuts, sesame and dried fruits; and a combination of amaranth with milk and grated coconut called "millcoco", as well as biscuits (ROCHA, 2003). Recipes to prepare 'alfajor' (two biscuits filled with caramel) with quinoa, quinoa pies and orange cake with cañihua flakes were also developed.

In Peru, taste tests of boiled grain flours and desserts as well as of cañihua-based dishes, were made. The process of expanded products for nougat elaboration was studied. The best combination of cañihua and corn was de-

[1] Norma Boliviana "Cereales-quinua-en grano-clasificación y requisitos"

termined to obtain expanded products by extrusion. With quinoa, malt procedure parameters have been studied for beer development and other parameters have been determined for the production of chocolate. Instant quinoa and cañihua have been obtained, with high nutrient and energy levels, at competitive production costs. A nutritious beverage from germinated cañihua and pineapple juice, with important nutrient properties and at competitive costs was developed. A coffee-type beverage of toasted cañihua was obtained and could compete with conventional coffee, having the advantage of being caffeine-free. Expanded popped grains with artificial flavouring and colouring could be introduced into the market in a competitive and successful way. Finally a liquor based on quinoa, pineapple and maca (*Lepidium meyenii* Walp.) was also developed.

Area 6: Research and development-oriented activities to strengthen national capacities.

Weak national capacities for tackling the promotion of NUS represent a common situation in most countries, both in developed and developing countries. Building capacities entails the enhancement of physical infrastructures, technologies and tools as well as education. With regard to human resources the project has been equally active. Since 2002 and continuing throughout 2005 (first phase) and during the start of the second phase (mid 2007-2008), many courses were carried out in communities collaborating with the project, targeting community members (particularly women), stakeholders in the value chains, students and researchers. More than 40 courses were undertaken by the project both in Bolivia and Peru, which have directly benefitted more than 2,000 people. These courses covered a broad range of themes, from surveying, collection, characterization of plant genetic resources to cultivation practices, participatory evaluation, harvest and post harvest technology, food technology, value addition, quality standards and marketing. In addition to the courses, also three manuals for the cultivation of Andean grains were produced and disseminated to communities during the courses. In addition 29 university students (from UNSA-Puno, UNA-Puno and EPG-UNA in Peru and UMSA and UTPO Universities in Bolivia) were trained in research fields of interest to the project (from conservation and cultivation to nutrition and marketing) while carrying out their thesis work. Capacity building on agri-tourism was initiated in 2008 in the community of Santiago de Okola to enable the local population to raise their incomes through the promotion of local agricultural biodiversity and the landcape.

Area 7: Establishment of effective links between conservation and crop value chains

Interventions along the value chain for each of the three Andean grains were made in a two-step approach in both countries. First an assessment was conducted of the value chains to map out their functioning, members, bottle necks and opportunities for their enhancement. Second, selected interventions were developed together with the stakeholders to address their weaknesses and limitations. To strengthen the links across value chain actors a number of initiatives were made, including the development of collaborative agreements, for example between Aiquile Municipality in Cochabamba (Bolivia) and the Local Amaranth Producers to provide school breakfast to local schools, or the agreement between two amaranth producer organizations also in Bolivia who signed agreements with the Andes Trópico Company for the regular supply of products to their factories. With regard to the value chain of quinoa and cañihua, three producer organizations signed purchase and sale agreements with the Andean Cereal Processor of La Paz. These agreements include commitments to deliver high quality products for higher prices (up to 20% higher than those present in the market at the time of the transaction) (SARAVIA and ROJAS, 2002). A particular case was the linking up of cañihua producers of the Llaitani community (Cochabamba) and the Irupana organic Andean food enterprise in La Paz. These links started in 2004 with the establishment of participative evaluation lots with accessions from the National Andean Grains Gene Bank and local variety grains. The work was supported with capacity building courses about the productive process of cañihua crops. Visits from the head of the Provider Development Area of Irupana to Llaitani community were promoted, starting a strong bond between two productive chain links of the cañihua crop.

Area 8: Development of policy and legal frameworks and public awareness

In both Peru and Bolivia seminars were held involving representatives of the Ministries of Agriculture and Commerce and from the private sector to discuss ways of promoting quality introduction of standards for Andean grains while maintaining diversity in production systems.

One fundamental task to promote quinoa, cañihua and amaranth in national and international markets is support in the development and review of technical regulations that determinate quality standards of Andean grains. Through a coordinated work with the Bolivian Institute of Quality and Standardization – IBNORCA, technical regulations for cañihua and quinoa were developed (IBNORCA, 2002), the first of their kind in the country and in the Andean region. This has allowed access to export markets, because exportation of products is not possible without the establishment of quality standards. Furthermore, the development of technical regulations for amaranth was supported as well as the revision and actualization technical regulations for quinoa.

These achievements were later supported by other projects managed by the PROINPA Foundation and, in the framework of the NOREXPORT Programme, a regional trade and capacity-building group, work is being done for the development of Andean technical regulations. The Projects for Andean Cereals Regulations are being negotiated, with the participation of representatives from the IBNORCA network and its counterparts in Colombia (ICONTEC), Ecuador (INEM) and Peru (INDECOPI). Furthermore, a project has been developed for the regulation of popped quinoa. The regulations developed allow quality standardization (in this case quinoa and processed products), contributing to better commercial flows, thus eliminating possible customs barriers (SOTO, 2008).

Using radio, television and newspapers, the nutritional value of cañihua, quinoa and amaranth has been promoted. Recently a strategic alliance has been established between the 'Alexander Coffee' coffee-shop chain[2], the PROINPA Foundation and 'La Paz on Foot'[3] (an eco-tourism organization) with the support of the Italian NGO UCODEP[4] and Bioversity International to implement a campaign to promote the consumption of these Andean grains. The campaign has had the purpose of informing customers about the nutritional benefits, agrobiodiversity, and recipes of the Andean grains through educational cards placed on the tables of the Alexander Coffee shops. Likewise, this company has developed novel products prepared with Andean grains. In the month destined for the promotion of quinoa, a quinoa cake, a quinoa "wrap", a quinoa salad and a new quinoa biscuits were also presented to the public with great success.

[2] www.alexander-coffee.com

[3] www.lapazonfoot.com

[4] www.ucodep.org

Recommendations on the Way Forward

For quinoa, increased demand for export to Europe is leading to booming cultivations both in Bolivia and Peru, often without any crop rotation. The impact of this practice on the fragile soils of the Andean region needs to be assessed in order to avoid negative repercussions on the agro-ecosystems that would jeopardize future cultivation. Sustainable cultivation practices need therefore to be developed to allow farmers to seize emerging income opportunities while maintaining both diversity and ecosystems functionalities.

Over the last five years, the variation in climate patterns has been very high in the Andes with profound effects on local cultivation. During participatory workshops with farmers, the IFAD NUS project has recorded an increase of production losses in Andean grains in the order of 23 % on average. Urgent studies are needed to assess the impact of climate change on the genetic diversity of Andean grains and evaluate how this can be better mobilized in order to mitigate risks associated with such changes.

As demand for functional foods and alternative non-food products (such as the industrial use of saponin) from Andean grains rises, more research should be directed towards the development of community-based technologies and capacity building interventions in order to empower farmers to benefit from these emerging opportunities.

Greater linkages should be created between biodiversity-rich but economically poor regions of the Andes and tourism companies so as to promote sustainable, community-based eco-tourism initiatives. Andean grains, like many other native crops from this region, can offer local populations profitable opportunities for income generation and a more holistic and multidisciplinary approaches for their promotion should therefore be emphasized.

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MICROEVOLUTION OF SCOLYMUS HISPANICUS L. (COMPOSITAE) IN SOUTH ITALY: FROM GATHERING OF WILD PLANTS TO SOME ATTEMPTS OF CULTIVATION

Laghetti Gaetano

> *'Plant Genetic Resources (PGR) belong to that part of biodiversity designated as economically important. Only with the aid of a comprehensive concept, which includes PGR for food and agriculture as well as the other potentially important plants, can the problem of conservation (which begins with gene erosion) be solved.'*
>
> Karl Hammer (2004)

Abstract

This is a short note about the rare cases of cultivation of *Scolymus hispanicus* L. in southern Italy. Traditionally all consumed plants of this species (most of all the leaf ribs) come from wild collections and are sold on local markets at high prices. In recent years some iformation about the agronomic management of this species and the phenotypical variation of wild and cultivated material has been collected. *S. hispanicus* might become an attractive new vegetable for many Mediterranean areas where it is already well known.

Key words:
agricultural biodiversity, collecting, common golden thistle, domestication, plant genetic resources

The Mediterranean region is the centre of origin of several crops and an important centre of diversification for introduced species (Hammer et al., 1992). Many wild relatives of crops are present in this area and many wild plants are used as food or for other purposes. Most of this diversity has been subjected to vast levels of genetic erosion due to the increased level of urban spreading, the changing socio-economic conditions, the destruction of natural environments for increased human activity and the rapid spreading of few modern cultivars.

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Italy belongs to the Mediterranean gene centre proposed by Vavilov (1927) and has a varietyof different ecological, pedoclimatic, and orographic conditions. The Italian flora therefore is rich in endemics and rare plants (Pignatti 1982) and many crops have their original domestication centre there, showing a wide genetic and phenetic variability. At the species level the loss of the existing genetic variation, proceeds relatively slowly in Italy, and most of the species mentioned under cultivation by earlier authors were still found in recent missions (Hammer et al. 1999) even in the surroundings of large cities (Hammer et al. 1996). However, there is a tremendous diversity loss at the ‘infraspecific level’. It is difficult to provide an exact estimation for this phenomenon per unit area, however, the general process can be demonstrated quite well by the decrease in the number of land-races under cultivation and by the increasing uniformity of modern agriculture (Hammer and Laghetti 2005). Crop genetic erosion appears to be overall more advanced in the lowlands than in the mountainous areas, and it has progressed further in the central and northern parts of Italy. There is another interesting result for the groups of crops: whereas genetic erosion is very high in field crops such as in cereals and pulses, garden plants are able to persist much longer (Hammer and Perrino 1995).

In Italy there is an ancient and widespread habit to gather wild plants as a source of food or for other uses (Bianco 1990, Ditonno and Lamusta 1997, Guarrera 2006). In some cases local farmers have started to cultivate some wild plants such as wild rocket (*Diplotaxis tenuifolia* (L.) DC., Hanelt 1986), *Silene vulgaris* (Moench) Garcke (Laghetti et al., 1994), wild mustard (*Sinapis alba* L. see Maly et al., 1987), wild asparagus (*Asparagus acutifolius* L.) and butcher's broom (*Ruscus aculeatus* L.), horse parsley (*Smyrnium olusatrum* L. see Laghetti et al., in press), *Calamintha nepeta* (L.) Savi and *Micromeria thymifolia* (Scop.) Fritsch. (Hammer et al., 2005). For many other plants, there is very little information on their utilization; common golden thistle or Spanish oyster thistle or Spanish salsify (*Scolymus hispanicus* L.) is one of these species.

S. hispanicus is a herbaceous biennial or short lived perennial diploid (2n = 20) species belonging to the Compositae. It is native to the Mediterranean basin and is present also in the Canary Islands, in Western Europe up to the northwestern France. In Italy the plant grows wild in all regions from 0 to 800 m asl., mainly in ruins, along the edge of the roads, on uncultivated lands, preferably in dry and sandy soils (Schönfelder and Schönfelder 1996). The botanical traits of common golden thistle growing in southern Italy are: erect and very spiny plants, stems 20-100 cm long branched at the top, oblonglanceolate and pinnatisect basal leaves with few spines and long petioles, stiff and spiny caulinar leaves; the capitula are bright yellow to orange yellow, 2-3 cm diameter and surrounded by an involucre of spiny bracts; hermaphroditic flowers, achenes ca. 3 mm long with a pappus characterized by a brief corona. *S. hispanicus* usually flowers in Italy from June to September.

The most common Italian folk names for the 'cardogna comune' or 'scolimo' or 'cardaburdue' (Italian common terms for *S. hispanicus*) are: 'sculimbru', 'sculimmi', 'scolimbrio' (Calabria region), 'cardogna', 'carduncello', 'carduncielle' (Campania region); 'maccarruni di chiana', 'sagalliemmiru', 'saittuni', 'scalimmiri', 'scoddi', 'scoddi di ripi di mari', 'scuoddu' (Sicily), 'cardu criéstu', 'cardunceddu', 'carduncieddu', 'cardunciedd', 'spagnulu' (Apulia region), 'cardon', 'lattarul', 'cardoncella' (Basilicata region).

'Cardoncella' was well known since the time of Theophrastus (371 – ca. 287 BC) in ancient Greece given its medicinal (having antisudorific, febrifuge and diuretic properties) and culinary uses. It was mentioned also by Pliny as a good antiperspirant. A Hispano-Arab document of the eleventh century reports that in Spain this wild spiny plant was collected to be eaten as vegetable. In the sixteenth century in Salamanca, the young plants were eaten with their root, either raw or in stews with meat. Until today, in many Spanish towns, the plant is commonly consumed in stew during the spring (Font Quer 1990). In soup, its roots are prepared with milk, butter and flour. In Turkey *S. hispanicus* is amongst the most popular wild plants used as a vegetable (Abak and Duzenli 1989). Additional information on its culinary uses can be find in Hawkes (1986), Hedrick (1919), Kunkel (1984), Organ (1960), Sevilla (1997), Tanaka (1976), Vilmorin-Andrieux (1885).

As in Spain, also in south Italy 'cardoncella' is habitually gathered from the wild given the delicate flavour of its leaves. In particular in Apulia the young basal leaves are eaten as vegetable in salads, boiled, in soups, vegetable broths, stews, omelettes and many other traditional recipes (Stanziano and Santoro 1991). The most savoury part of the leaf is the central rib, a white fleshy part which is obtained by peeling the spiny leaf with a very typical movement of the hand from the base to the apex (Fig. 1c). Also in Basilicata region, local people collect 'cardoncella' from spring to summer (Caneva et al., 1997). Giusti et al. (2002) describe the collecting and preparation of the 'kardunxheljë' (*S. hispanicus*) in some towns of Albanian origin of the Vulture area (Basilicata region) where, during Easter time, the leaves of this plant are one of the main ingredients of the famous local recipe the 'verdhët'. In some zones of southern Apulia the petals of *S. hispanicus* are used as saffron surrogate (Palombi 2005).

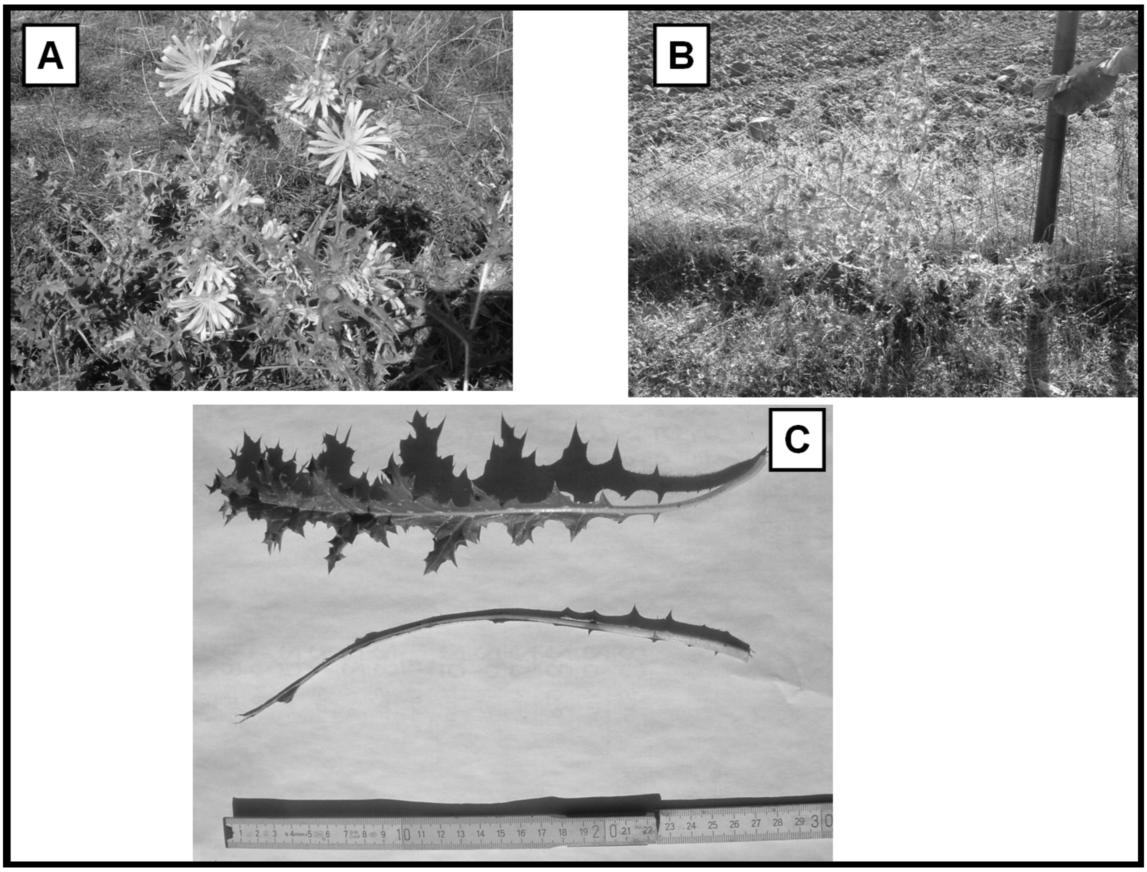

Figure 1. Wild plants of *Scolymus hispanicus* growing in the countryside of Lavello town (Basilicata region) [A]; a row of cultivated plants of *S. hispanicus* along the fencing of a small farm located in the same area of the previous picture [B]; the most used part of this plant is the central leaf rib [C, centre], a white fleshy part which is obtained by peeling the leaf [C, upper].

Guarrera (2006) in his book on 'Italian folk medicine and ethnobotany' describes the culinary use of the stewed root bark of *S. hispanicus* together with its forage and medicinal utilization. Facciola (1998) reports that the fleshy roots of this plant (called also 'Cardillo' and 'Golden thistle') are eaten boiled, mashed, baked, or used as a substitute for coffee, while the young, tender leaves and blanched leaf-stalks are much appreciated in Madrid as a cooked vegetables dressed with olive oil, salt and vinegar. Hammer et al. (1992, 1999) in their two catalogues of 'crop germplasm in Italy' cited *S. hispanicus* with further details, referring also to its 'possible former cultivation'. According to Hernández Bermejo and León (1994) it is occasionally cultivated in Mediterranean countries such as Spain, Greece and the Maghreb.

The main aim of this paper is just to report and discuss about the rare cases of cultivation of *S. hispanicus* in southern Italy.

The presented data and information come from a number of exploration and collecting missions carried out jointly by Italian-German teams from Institute of Plant Genetics (IGV), Bari (Italy) and the Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK), Gatersleben (Germany) summarized in Hammer et al. (1992).

Currently most of the *S. hispanicus* plants consumed in south Italy comes from wild collections. Often the leaf ribs are sold in local markets, and today also in some supermarkets, at prices of. € 8,00-10,00 per kilo of peeled leaves. This is one of the main reasons why some farmers and small horticulturists started to cultivate *S. hispanicus* in their gardens (Fig. 1b). In Basilicata a number of old farmers told us that this practice is very ancient in the area even if the main target is the family consumption and the sale on local markets. Other specific reasons for the cultivation of this species are: a reduction of uncultivated fields often due to the increased level of urban spreading, the destruction and pollution of natural environments for increased human activity, the security of eating an un-polluted product, convenience for old collectors physically unable to reach more distant collection areas, hobby.

According to the interviewed farmers the cultivation of 'cardoncella' is not very difficult because the plant is resistant to cold and diseases, grows in all kinds of soils, even if it prefers those rich in organic matter and light-texture. Traditionally, from the end of winter to spring, the plants are propagated by direct sowing, whereby seeds have a very high germination rate during several years and do not exhibit marked dormancy. Usually the species is sown in furrows 25-35 cm apart with a distance of ca. 30 cm between plants on rows after thinning. Typically the young shoots are pulled up when they are about 20 cm height while the roots are harvested from November to February. In Basilicata 'cardoncella' is cultivated as an annual crop because, as it becomes older, its stems and leaves lose their appreciated tenderness and taste.

To my knowledge no specific study has been conducted about the genetic variation of this species and its nutritional value,. A considerable phenotypic variability was observed in southern Italy during the many exploration missions by IGV's collecting team, regarding: spininess, pubescence, leaf and receptacle morphology and size, plant vigour, flower colour. During the last collecting missions in Basilicata special attention was paied to detect the differences between the cultivated plants of *S. hispanicus* and the wild ones growing in the neighbouring areas from where, very probably, the cultivated ones originally came from. The cultivated material has, in comparison with the wild one, the following characteristics: the caulinar leaves have less, smaller and softer spines (Fig.1a and 1b) facilitating the handling of plants; the central leaf rib is thicker, more tender and juicy. The prospects for genetic improvement and better management seem very wide and promising.

In conclusion *S. hispanicus* might represent an attractive new vegetable for many Mediterranean areas where it is already well known. Plant breeding projects are needed to develop cultivars attractive to farmers.

Availability of Germplasm

So far no significant collection or conserving efforts have been made for *S. hispanicus*. IGV stores very few accessions of *S. hispanicus* while larger collections of accessions exist according to Facciola (1998) at IPK, at the Jardin Botanique at Angers (France) and at Nikita Botanical Gardens, Yalta (Ukraine).

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COLLECTING PLANT GENETIC RESOURCES IN UPPER SVANETIA (GEORGIA, CAUCASUS MOUNTAINS) 2008

Klaus Pistrick, Maia Akhalkatsi, Tamar Girgvliani and Tamasi Shanshiashvili

Abstract

A joint exploration was carried out by staff members of the Botanical Garden and Institute of Botany, Tbilisi and the Leibniz-Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben, in August 2008 to study plant genetic resources in the isolated Caucasus region of Upper Svanetia, Georgia. In a very short time, restricted by the outbreak of the military conflict, 56 accessions, mainly of pulses, spices and vegetables could be collected. In several communities around the town of Mestia, still a large variability of traditional crop plants remains in cultivation. Even relic crops, such as *Panicum miliaceum*, *Pisum sativum*, *Lens culinaris*, and *Vicia faba* could be found.

Key words:
Caucasus, collecting mission, Georgia, plant genetic resources

Introduction

The territory of Georgia is very important for the study of plant genetic resources. It belongs to the Near Eastern region of diversity of cultivated plants (Vavilov 1935, Zeven and de Wet 1982). Several endemic taxa of cereals and legumes (*Triticum*, *Pisum*, *Vicia*) have been reported from this area (Hanelt and Beridze 1991). The ancient agricultural tradition can be documented by archaeological remains of crop plants from the 5th/6th millennium B.C. (Schultze-Motel 1989).

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Recent joint activities of the Tbilisi Botanical Garden and Institute of Botany and the Leibniz-Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben, continue the close Georgian-German cooperation in the field of plant genetic resources of the 1980s (Hanelt and Beridze 1991) as well as explorations in the frame of the project “Pharmaceutical values of onions and related species (*Allium* L.) of Middle Asia and the Caucasus (PharmALL)” (Pistrick et al. 2008). Existing gene bank collections should be enriched and former results compared with the *status quo*, contributing substantially to the conservation of plant genetic resources and the investigation of genetic erosion as suggested by Hammer and Teklu (2008).

Table 1: Chronology of the collecting mission to Georgia (Caucasus Mountains from August 5th to 11th, 2008

5./6.8.	Flight from Frankfurt a.M. to Tbilisi. Discussion on the programme of excursions and final preparations. Travel to Kutaisi. Collection at the northeast border of the town and at Gelati (350m asl).
7. 8.	Travel to Mestia via Zugdidi, Chaiši and the Inguri gorge.
8.8 – 10.8.	Basis quarter in Mestia. Daily excursions in Upper Svanetia.
8.8.	Excursions to Leli, southeast of Mestia and to Lalaida and Laghami, northwest of the town (1450 – 1600m asl).
9.8.	Excursion in southwest direction to the Latali community. Collecting in the villages of Macchvariši, Škaleri, Lachušdi and Kvančianuri (1300 – 1350m asl).
10./11.8.	Breaking off of the mission due to war conditions. Travel back to Zugdidi and via Senaki, Samtredia, Kobuleti, Batumi to the Turkish border at Sarpi. Return to Tbilisi via Achalciche, respectively Istanbul and flight to Frankfurt a.M.

Field work of the 2008 collection in Georgia started on 8 August, but had to be abandoned due to the war conditions in the country two days later (Table 1, Fig. 1). Nevertheless some impression of the recent situation of plant genetic resources in the surroundings of the town of Mestia, Upper Svanetia and some remarks on the plant material collected have been obtained.

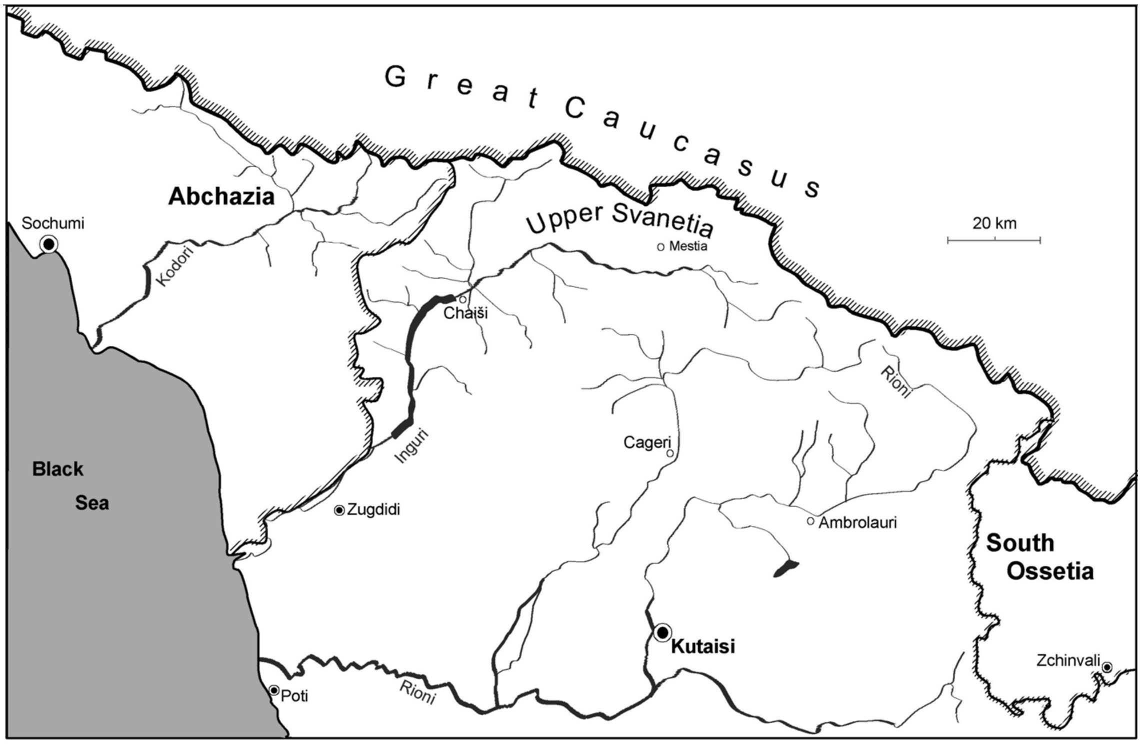

Figure 1: Area of the 2008 collecting mission in Georgia

Results

Upper Svanetia is an isolated mountainous region of Georgia, situated in the basin of upper Inguri and its tributaries, south of the main ridge of the Great Caucasus (Fig. 1). For several years it was not easy to travel to this region after the Abchazia conflict. Reportedly, genetic erosion further increased especially in cereals, compared with the situation in the beginning of the 1980s (Beridze et al. 1982, 1985). However, changes in land use were much less drastic than in Eastern European high mountainous areas, where the specialization on cattle breeding caused radical conversion of all arable land into grassland (Pistrick et al. 1995). Especially in the large house gardens, a great diversity of indigenous landraces and local varieties of vegetables, pulses and spice plants continues to be grown (Fig. 2). A total of 56 accessions could be obtained (Table 2) in addition, herbarium material (22 numbers in 30 sheets) was collected, including cultivated and locally used plants and their wild relatives.

Figure 2. Images of the area around Landžeri in Upper Svanetia (Georgia), summer 2008.

In villages of Upper Svanetia, as Landžeri with the typical mediaeval peels (Figure 2), a great diversity of traditional crop plants is still cultivated in large house gardens. At Kvančianuri (below) *Capsicum annuum, Zea mays, Solanum tuberosum, Brassica oleracea* var. *capitata, Ocimum basilicum, Cucumis sativus, Tagetes erecta, Phaseolus vulgaris* var. *vulgaris, Lycopersicum esculentum, Anethum graveolens* and *Lactuca sativa* are grown at 1350 m together with *Panicum miliaceum, Allium fistulosum, Phaseolus vulgaris* var. *nanus, Trigonella caerulea*, and *Vicia faba.*

Table 2: Material collected during the 2008 collecting mission in Georgia

Crop	No. of accessions	Sum
Avena sativa L.	1	
Hordeum bulbosum L.	1	
Panicum miliaceum L.	2	
Zea mays L. convar. *mays*	3	
Triticum aestivum L.	1	
Cereals and grasses		8
Brassica napus L.	1	
Brassica oleracea var. *capitata* L.	1	
Cucumis sativus L.	2	
Daucus carota L.	1	
Solanum tuberosum L.	3	
Vegetables and cucurbits		8
Phaseolus vulgaris var. *nanus* Asch.	5	
Phaseolus vulgaris L. var. *vulgaris*	5	
Pisum sativum L.	2	
Lens culinaris Medik.	1	
Vicia faba L.	4	
Pulses		17
Allium cepa var. *aggregatum* G. Don	2	
Allium sativum L.	2	
Allium fistulosum L.	2	
Anethum graveolens L.	1	
Apium graveolens L.	2	
Coriandrum sativum L.	5	
Petroselinum crispum (Mill.) Nym.	1	
Tagetes patula L.	1	
Trigonella caerulea (L.) Ser.	5	
Spices		21
Vicia sp	1	
Fragaria vesca L.	1	
Other crops and wild relatives		2
TOTAL		**56**

Cultivation of indigenous wheat (Girgvliani 2001) completely disappeared in the collection area and new introductions of *Triticum aestivum* from lower altitudes have obviously not been very successful under the conditions of Upper Svanetia. *Panicum miliaceum* (Svanish: pat'v), another ancient indigenous cereal plant, could still be collected at Kvančianuri and Ieli as a relic crop in a diverse mixture of different seed types (Fig. 3). However, most of the former millet cultivation has been replaced by the now dominating maize, introduced in Upper Svanetia probably in 1911 (Girgvliani 2001). The material collected of some older landraces of flint corn (*Zea mays* convar. *mays*) has cream coloured and red-brown grains. Second to maize, potatoes (*Solanum tuberosum*) are the staple food in the region. Older varieties with brown and violet red tubers were obtained. Similar to cereals, also in pulses an introduction from the New World (*Phaseolus vulgaris*) widely replaced ancient indigenous taxa (*Vicia faba*, *Pisum sativum*, *Lens culinaris*) in cultivation. Common bean, introduced into the western part of Upper Svanetia before the beginning of the 20th century (Girgvliani 2001), developed in Georgia a secondary centre of variability (Beridze and Hanelt 1991, Hanelt 2004). The great number of seed variants cultivated in the restricted collecting area is comparable to that one reported from Western Carpathians (Fig 4; Kühn et al. 1982). Many old traditional legumes could still be found in cultivation in the village of Ieli (1600 m). Great variability showed especially the accessions of the rare relic crops *Pisum sativum* (12 seed types) and small seeded *Lens culinaris* (18 seed types). Faba beans are grown in several other villages (Lalaida, Lag'ami, Kvančianuri) as well. A broad spectrum of local spice plants is cultivated in many house gardens (Fig. 2). Remarkable variation in seed colour show all accessions of sweet trefoil (Fig. 3), widely used in the Georgian kitchen. The Svanish vernacular name "šambrikai" is completely different from the Georgian "uccho suneli", indicating the long time of cultivation in Svanetia.

For a more detailed assessment of the recent situation of plant genetic resources in Svanetia the exploration mission has to be continued very soon.

Variable seed colour indicates considerable genetic diversity in landraces of quite different taxa, such as *Trigonella caerulea* (Leguminosae; left) and *Panicum miliaceum* (Gramineae; right). The sample no. 48 (left) from Lachušdi consists of equal proportions of the following seed colours: blackish violet, olive green with dense violet spots and dots, yellowish green to olive green with scattered violet spots and dots, and greenish yellow without spots and dots (from the top). In accession no. 51 (right) from Kvančianuri grey and yellow coloured grains (top and third from the top) dominate some admixtures of yellowish grey (second from the top) and white grains (below).

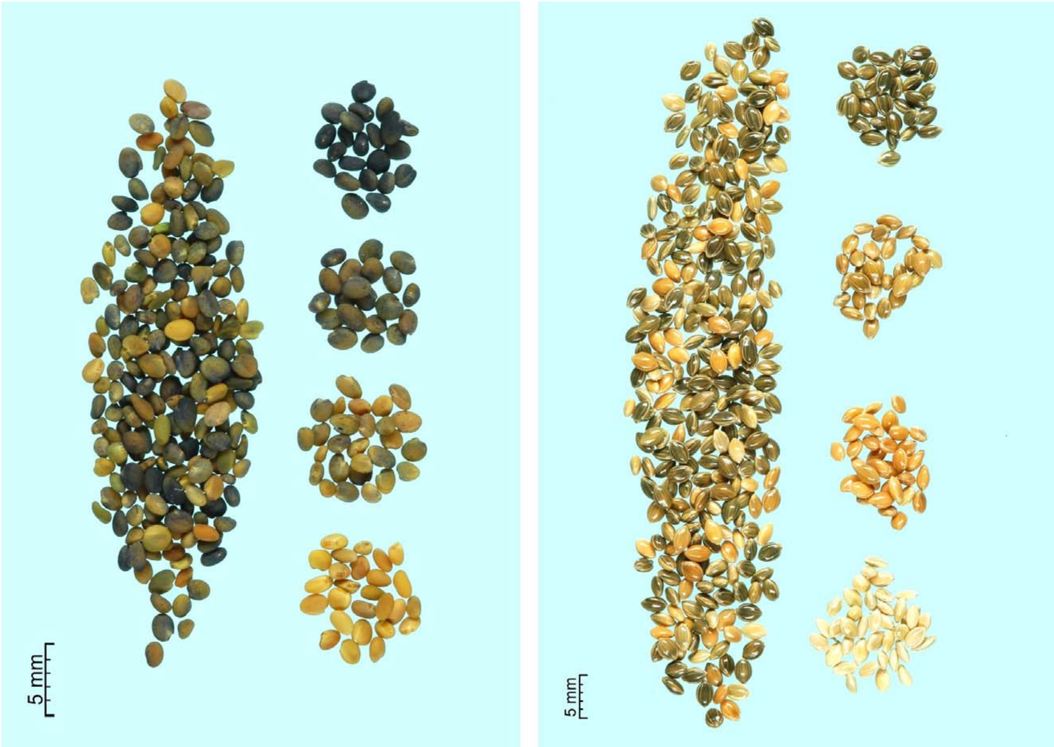

Figure 3. Seeds of *Trigonella caerulea* (left), *Panicum miliaceum* (right) from landraces collected in summer 2008 at Kvančianuri and Jeli, Upper Svanetia (Georgia).

Figure 4. Seeds of *Phaseulus vulgaris* collected in the Western Carpathians (Kühn et al. 1982).

Seed variants of the garden beans from the Upper Svanetian communities Latali, Mestia and Ieli. Upper three rows: *Phaseolus vulgaris* var. *vulgaris*, Lower two rows: *Phaseolus vulgaris* var. *nanus*. Colours from left to right:

1st row – beige with brown edge and yellowish brown halo around the hilum; beige with brown dots and with brown edge and violet grey halo around the hilum; yellowish brown with brown edge and yellowish brown halo around the hilum; violet red with translucent brown edge and yellowish brown halo around the hilum; violet red with blackish red edge around the hilum.

2nd row – black; beige with violet stripes, spots and dots and with brown edge and yellowish brown halo around the hilum; the same colour as before; white with greyish violet round blotches, greyish violet covered from the hilum side with translucent brown edge and yellowish brown halo around the hilum; beige with greyish brown stripes and spots and with brown edge and yellowish brown halo around the hilum.

3rd row – beige, nearly completely covered by greyish brown stripes and spots and with brown edge and dark yellowish brown halo around the hilum; beige, blackish brown marbled with greyish brown and black stripes and spots and with dark brown edge and yellowish brown halo around hilum; beige with blackish violet stripes and spots and with brown edge and yellowish brown halo around hilum.

4th row – white; beige with brown edge and yellowish brown halo around hilum; yellowish brown with brown edge and yellowish brown halo around hilum; yellowish brown with brown edge and violet grey halo around hilum; violet red with brownish red edge round hilum; the same colour as before.

5th row – blackish violet with black edge and blackish brown halo around hilum; white with grey and black stripes and spots and pink at the hilum side with pink edge and white halo around hilum; white with round dark violet red blotches and dark violet red at the hilum side; beige with dark violet red stripes, spots and dots and with brown edge and yellowish brown halo around hilum; beige, black marbled with black stripes and spots and with a translucent brown edge and yellowish brown halo around hilum.

Acknowledgements

The authors would like to thank Svanetian farmers and their families for their substantial help in the field, the Gemeinschaft zur Förderung der Kulturpflanzenforschung Gatersleben for kindly supporting the mission, B. Schäfer and U. Tiemann for photographical work and drawing the map and A. Diederichsen for a language check.

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HOST PLANT RESISTANCE AND TOLERANCE OF *MUSA* LANDRACES AND HYBRIDS TO NEMATODE INFESTATION

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Abstract

A field experiment was established in the humid forest of southeastern Nigeria to assess host plant response to nematodes. Fifteen polyploid plantain and banana cultivars (landraces and hybrids) were tested in nematode-infested and non-infested fields on both plant and ratoon crops. The main nematode species observed in this experimental field were *Radopholus similis*, *Helicotylenchus multicinctus*, *H. dihystera* and *Meloidogyne* spp., and in negligible amounts *Hoplolaimus pararobustus*. Plant height, root health assessment and nematode densities were determined before flowering, at flowering and in harvested plants. Bunch weight and toppling incidence was compared between infested and non-infested plants. The average yield loss due to nematode infestation was 29%. Principal component analysis of nematode densities and root damage helped in developing a score considering all traits measured for host plant response to nematode infestation. The bi-plot of the first principal component versus plant height reduction allowed to cluster the cultivars into distinct groups. The recording of host plant resistance to nematodes (as measured by their densities and root damage) as well as measurement of plant traits such as height and bunch weight allowed to identify resistant and tolerant cultivars to nematode infestation at this location. For example, the tetraploid banana hybrid SH 3640 and the triploid banana cultivar Yangambi-km5 showed low damage due to nematodes and did not reduce significantly their plant height. Hence, SH 3640 was rated as the solely resistant cultivar among those tested in this experiment.

Key words:
burrowing nematode, damage assessment, nematode reproduction, resistance, root lesion nematodes, susceptibility, tolerance, yield loss.

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Introduction

Plantain and banana (*Musa* spp.) are important food crops worldwide with a total production of 95 million t in 2000, of which one third was produced in sub-Saharan Africa (FAO 2001). Dessert bananas comprise 53% of total production, while cooking bananas account for 47% (Lescot 1998). Unfortunately, pest and diseases threaten *Musa* production. Major constraints to banana production are nematodes, the banana weevil (*Cosmopolites sordidus*), and black Sigatoka (*Mycosphaerella fijiensis*) (Stover and Simmonds 1987). In Nigeria the most serious nematode pests are *Radopholus similis*, *Helicotylenchus multicinctus*, and *Pratylenchus coffeae*. Also root knot nematodes (*Meloidogyne* spp.) can cause serious damage (Speijer and Fogain 1999).

Nematodes feed, multiply and migrate in the banana roots and rhizome, resulting in a necrotic and reduced root system. *Meloidogyne* spp. induce feeding cells, resulting in root galls and club-like deformation of the root system (Speijer and De Waele 1997). Nematode affected plants are reduced in their ability to uptake water and nutrients, which can result in a delay in time to flowering and ratooning, and in a reduced bunch size. Also, plant anchorage is affected, resulting in plant toppling, especially at bunch filling (Stover and Simmonds 1987). As a result of lower yield and higher incidences in toppling, production losses of up to 90% in plantain cv. Obino l'Ewai, due to a combined *R. similis and H. multicinctus* infestation, have been reported in Nigeria (Speijer and Fogain 1999).

Nematodes can be controlled with chemicals, but those are costly and have adverse environmental effects. An alternative and promising strategy is developing *Musa* cultivars with resistance to nematodes (Speijer and De Waele 1997). However, sources of resistance first need to be identified in *Musa* germplasm. Hence, the aim of this research was to evaluate the host plant response of *Musa* cultivars to nematode infestation.

Materials and Methods

Site Details

A field experiment was established in the humid forest zone in southeastern Nigeria at the High Rainfall Station of the International Institute of Tropical Agriculture (IITA) at Onne, to evaluate the host plant response to nematode infestation. The station is representative of the degraded humid forest zone with an annual average rainfall of 2400 mm (Ortiz et al. 1997). The average relative humidity values ranged between 78 to 89% throughout the year. The soil is a highly leached acid Ultisol, with poor chemical properties, nutrient deficiencies and soil acidity (Ortiz et al. 1997). Prior to planting the trial, *Pueraria* spp. was grown for one year on the research field as a cover crop.

Experimental Details

Fifteen cultivars were planted in a split-plot design using five replications. Nematode infested and nematode free plots were the main plots, while the subplots consisted of each of the cultivars. Each replication included four plants. The cultivars tested belong to the AAA dessert banana (Yangambi km 5 and Valery), AAB dessert banana (Pisang Ceylan), ABB cooking banana (Bluggoe and Cardaba), AAB plantain (Obino l'Ewai and Mimi Abue) groups, or were polyploid hybrids derived from dessert bananas (FHIA-1, SH 3640 and SH 3436-9), plantains (FHIA-22, TMPx2796-5 and TMBx548-9) and cooking bananas (FHIA-3, FHIA-23).

In vitro plants were used as planting material. At planting, plants in the nematode infested plots were inoculated by mixing 250 g necrotic banana root segments containing a mixture of nematodes (*R. similis*, *H. multicinctus*, *H. dihystera*, *Meloidogyne* spp.) in the planting hole. The non-infested plot was treated with Nemacur at a rate of 15 g active ingredient (fenamiphos) per plant twice a year.

Data Collection

Data were taken before flowering (that is 9 months after planting), at flowering and at harvest of the mother plant (or plant crop) and the first ratoon (or ratoon crop). Data were not recorded before flowering for the cultivars Mimi Abue and Pisang Ceylan because their root system was still very poorly developed. Likewise, data were not recorded in the ratoon crop for Mimi Abue and FHIA-22 due to their retarded growth. Plant height was measured and root health assessed as described by Speijer and Gold (1996). Before flowering and at flowering, roots were collected from 20 x 20 x 20 cm holes excavated adjacent to the rhizome of the mother plant. At harvest, a sucker was collected.

Observations included counting the number of dead and functional roots. The root necrosis index for five functional roots was estimated using the method described in Speijer and De Waele (1997). At harvest, the number of lesions on the rhizome of the collected sucker was counted. The five functional root segments used for root necrosis scoring were cut into 0.5 cm sections, completely mixed and a 5 g sub-sample was removed for nematode extraction. After maceration of this sub-sample, nematodes were extracted overnight using a modified Baermann funnel method (Hooper 1990). The nematode counts were done three times using 2 ml aliquots out of a 25 ml volume containing all extracted nematodes. In case of high nematode densities, the volume was diluted to 50 ml. Nematodes were identified to species level and densities were given per 100 g root fresh weight.

Data were log (x+1) transformed prior to analysis (Gomez and Gomez 1984). Principle component analysis was used to understand the patterns of multi-trait variation (SAS 1989). Student's t-test was used to compare damage parameters, nematode densities, plant height and bunch weight between nematode infested and non-infested plants.

Results

Pre-flowering

The banana hybrid SH 3436-9 (with a density of only 130 nematodes per 100 g roots) and the banana cultivar Yangambi-km 5 (1,520 per 100 g roots) were poor hosts for *R. similis* in the infested plots. Good hosts for *R. similis* were Valery, FHIA-22 and TMPx 548-9 with more than 20,000 nematodes per 100 g roots. The other cultivars showed intermediate nematode densities. Bluggoe, TMPx 2796-5 and FHIA-1 appear very good hosts for both *H. multicinctus* and *H. dihystera*. All the cultivars supported reproduction of *Meloidogyne* spp., which accounted for the non-significant differences in population densities. *Hoplolaimus pararobustus* was also found but in negligible densities.

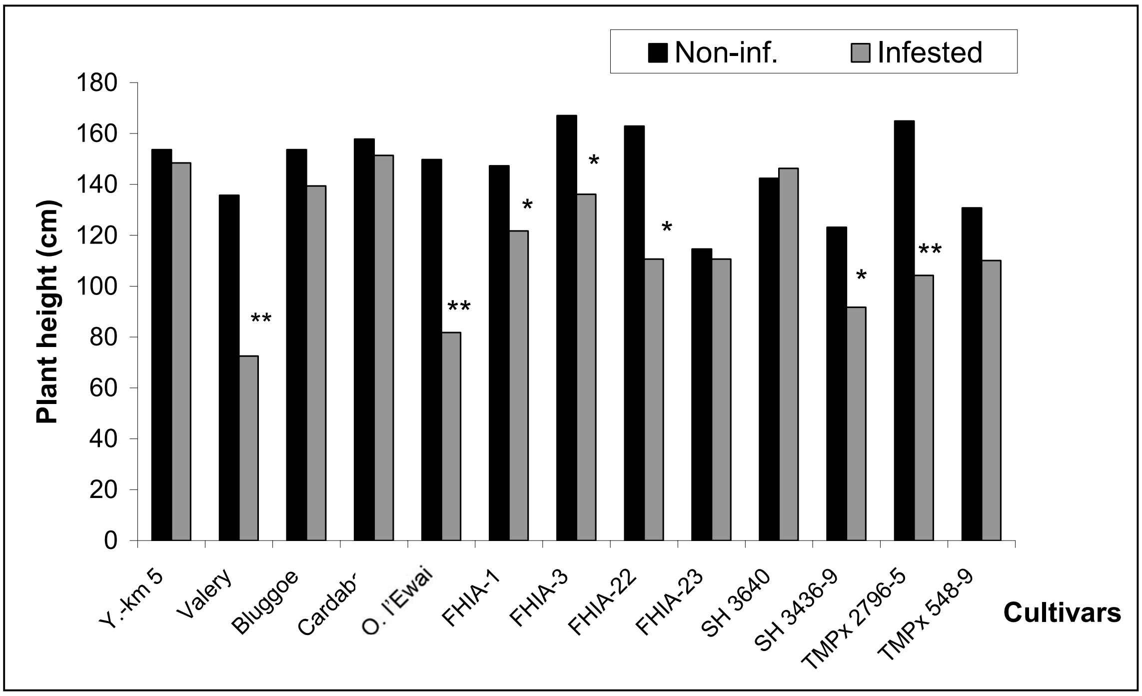

Figure 1. Plant height (cm) at pre-flowering of banana and plantain cultivars in nematode-infested and non-infested plants in a field trail in southeastern Nigeria.

*, **, *** indicate that means are significant different to the control (non-infested plot) according to Student's t-test at P ≤ 0.05, P ≤ 0.01, and P < 0.001, respectively

Table 1. Nematode densities in 100 g roots, root necrosis and percentage dead roots of infested plants at pre-flowering, compared to the non infested plot for different cultivars of bananas (*Musa* spp.) in a field trail in southeastern Nigeria.

Cultivar	*R. similis*	*H. multicinctus*	*H. dihystera*	*Meloidogyne* spp.	*Hoplolaimus*	Root necrosis	Dead roots (%)
Yangambi-km 5	1,520	4,194	3,927	16,627	1,130	15ns	15.2
Valery	28,161	7,550*	5,816	8,328*	1,883	35**	18.8
Bluggoe	2,367	40,331*	27,168**	16,164	2,031	16**	28.9
Cardaba	8,764	19,220*	13,197***	6,627	2,031	19**	26.0
Obino l'Ewai	8,494	18,097	9,661*	14,131	1,827	46**	13.9
FHIA-1	7,857	25,194*	19,167**	16,098	1,297	44**	14.15*
FHIA-3	2,630	19,724	8,060***	6,757	1,367	33**	40.6
FHIA-22	22,825	12,167**	10,325	33,325	667	31*	22.4
FHIA-23	6,230	20,597**	17,131**	8,657	267	29ns	28.2
SH 3640	2,034	8,861*	8,267**	6,697*	734	35ns	16.5**
SH 3436-9	130	10,227*	10,527**	14,060	30	54*	24.8**
TMPx 2796-5	14,034	31,794**	24,094*	11,731	3,060	48***	19.4
TMPx 548-9	21,967	25,927***	15,057**	16,590*	1,667	43**	13.9*

, **, * indicate that means are significant different to the control (non-infested plot) according to Student's t-test at $P \leq 0.05$, $P \leq 0.01$, and $P < 0.001$, respectively*

The root necrosis indices between the infested and non-infested plots were not significantly ($P \geq 0.05$) different for Yangambi-km 5, FHIA-23 and SH 3640. However, the root necrotic indices for the remaining cultivars were significantly different (Table 1). There were no differences ($P \leq 0.05$) for the percentage dead roots in the infested and non-infested plots, except for the cultivars FHIA-1, SH 3640, SH 3436-9 and TMPx 548-9 (Table 1). The percentages of dead roots were lower in the nematode infested plots.

The plant height of the cultivars Yangambi-km 5, Bluggoe, Cardaba, FHIA-23, SH 3640 and TMPx 548-9 were not affected ($P > 0.05$) by nematodes. The remaining cultivars showed a significant reduction in plant height compared to the non-infested plants (Figure 1). The most affected were the dessert banana Valery and the plantain Obino l'Ewai.

Principal components with an eigenvalue greater than 1 were retained for further analysis following Kaiser's criterion. The first three principal components, with a cumulative proportion of 0.769, followed this criterion (Table 2). In excess of ¾ of the total variation was therefore accounted by the first three principal components. Principal component 1 (Prin1) was mainly loaded by *R. similis* and *H. multicinctus* densities, and the percentage of dead roots. Principal component 2 (Prin2) comprised mainly *Hoplolaimus pararobustus* densities, whereas principal component 3 (Prin3) was loaded mainly by *Meloidogyne* spp. and *H. dihystera* densities, and the root necrosis index. The bi-plot of plant height reduction (%) versus Prin1 clearly indicates that cultivars susceptible to both *R. similis* and *H. multicinctus*, and with a great percentage of dead roots, had a significantly reduced plant height (Fig. 2,upper right quadrant).

Table 2. Eigenvectors, eigenvalues, proportions and cumulative proportions of principal components (PRIN) of the root damage indices before flowering of banana (*Musa* spp.) in a field trail in south-eastern Nigeria.

	Prin1	Prin2	Prin3
R. similis	0.503	-0.309	0.099
H. multicinctus	0.467	0.209	-0.401
H. dihystera	0.271	0.470	-0.552
Hoplolaimus	0.339	-0.539	0.037
Melodoigyne	0.177	0.177	0.446
Dead roots (%)	-0.439	0.187	-0.054
Necrosis index	0.342	0.339	0.439
Eigen value	2.706	1.367	1.312
Proportion	0.387	0.195	0.187
Cumulative proportion	0.387	0.582	0.769

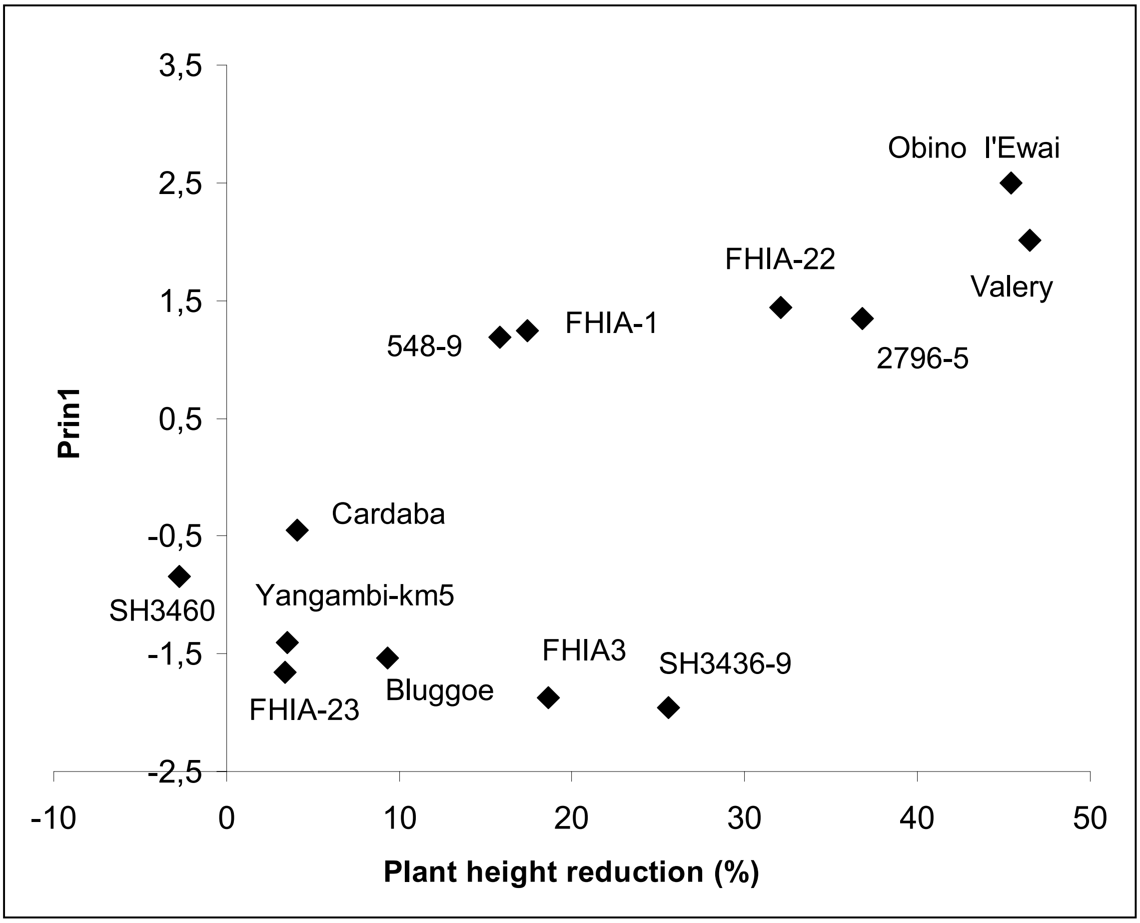

Figure 2. Biplot of plant height reduction (%) versus first principal component prin1 (with main positive loadings by R. similis, H. multicinctus and Hoplolaimus densities and dead roots percentage as main negative loading) before flowering of banana (*Musa* spp.) in a field trail in southeastern Nigeria.

Flowering

Good hosts for *R. similis* were TMPx 548-9 and SH 3640 with 11,930 and 17,320 nematodes per 100 g roots in the plant crop, respectively. Mimi Abue showed very low counts, while Pisang Ceylan supported no *R. similis*. High densities of *H. multicinctus* were found on all cultivars, except for the plantains Obino l'Ewai and Mimi Abue. Counts for *H. dihystera* were relatively low for all cultivars, with a maximum of 5780 nematodes per 100 g fresh roots for FHIA-23. *Hoplolaimus pararobustus* was also found but in minor densities whereas the cultivars tested showed a varied response to *Meloidogyne* spp. Similar results were observed in the ratoon crop.

There were no significant differences for root necrosis between infested and non-infested plants for Yangambi-km 5, Mimi Abue and Pisang Ceylan (Table 3). All the other cultivars showed significant differences. Yangambi-km 5, Pisang Ceylan, FHIA-1, FHIA-3, FHIA-22, FHIA-23 and SH 3640 showed no significant difference for percentage dead roots between infested and non-infested plants.

The plant height for the cultivars Yangambi-km 5, Valery, Mimi Abue, Pisang Ceylan, Bluggoe, Cardaba, FHIA-3, SH 3640 and TMPx 548-9 were not significantly different between the infested and non-infested plants (Fig. 3, $P > 0.05$). Plant height was significant different for the other cultivars.

PRIN1 was negatively loaded mainly by the percentage dead roots and *R. similis* densities, and positively loaded by the root necrosis index, *Hoplolaimus* and *M. incognita* densities (Table 4). The taller the cultivars, the lower the root necrosis index and the higher their host plant resistance to burrowing nematode at flowering (Fig. 4).

Table 3. Nematode densities in 100 g roots, root necrosis and percentage dead roots of infested plants at flowering, compared to the non infested plot for the different cultivars in the plant and ratoon crops of banana (*Musa* spp.) in a field trail in southeastern Nigeria.

Cultivar	*R. similis*	*H. multicinctus*	*H. dihystera*	*Meloidogyne* spp.	*Hoplolaimus*	Root necrosis	Dead roots
A. Plant crop							
Yangambi-km 5	2,745**	10,804***	1,217	11,795	2,312	5.8	19
Valery	8,828***	10,646***	2,785**	2,541	361*	28.8***	28.2**
Mimi Abue	625	1,396	1,229	719	166	8.5	55***
Pisang Ceylan	0	10,563**	2,979*	4,573	500*	13.1	23.2
Bluggoe	2,233**	9,024***	2,562***	6,142**	804	16.3***	20.3***
Cardaba	8,750*	11,500***	2,341**	5,567	854*	18***	22.7***
Obino l'Ewai	4,687	3,717	1,525	800***	487	27.5**	43**
FHIA-1	8,633***	15,937***	2,687**	6,350	2,391	12.3**	19.3
FHIA-3	2,791***	9,937***	1,700	5,629	1,508	13.7**	22.2
FHIA-22	1,614*	5,906*	698	2,375	312	25*	24
FHIA-23	1,308*	13,417***	5,783***	3,212*	391	23.2***	11.8
SH 3640	17,321***	15,250***	2,804***	6,824	2,858	13.1**	28
SH 3436-9	1,741***	9,496***	6,125	5,241	845	26.6***	11.5*
TMPx2796-5	5,829***	10,262**	2,592	6,629	867	22.3***	28.4*
TMPx548-9	11,933**	8,358***	1,958*	3,133	208*	28.5***	33.8***

B. Ratoon rop							
Yangambi-km 5	2,392***	6,608***	2,150***	5,187	671	14	13
Valery	15,102***	6,361***	4,333***	2,194	139*	27***	28
Bluggoe	1,042	15,854*	14,250***	5,146	323	21**	17
Cardaba	5,940***	15,738***	12,714***	5,236	869	28***	23
Obino l'Ewai	3,393***	7,601**	3,595***	2,101	119*	24***	12*
FHIA-1	2,759***	9,175***	5,819***	4,880**	764*	21***	11
FHIA-3	907**	7,265**	4,181***	4,314	564	20**	12**
FHIA-23	160	18,602***	11,154***	3,430	90	26**	20
SH 3640	1,954***	7,716***	4,519***	2,504	287	26***	19*
SH 3436-9	1,617*	12,055***	7,305***	4,367*	506	22	11
TMPx 2796-5	5,611***	14,507***	5,222***	3,340	597	27***	35***
TMPx 548-9	15,407***	11,926**	7,583***	8,093*	139	25***	10

, **, * indicate that means are significant different to the control (non-infested plot) according to Student's t-test at P ≤ 0.05, P ≤ 0.01, and P < 0.001, respectively*

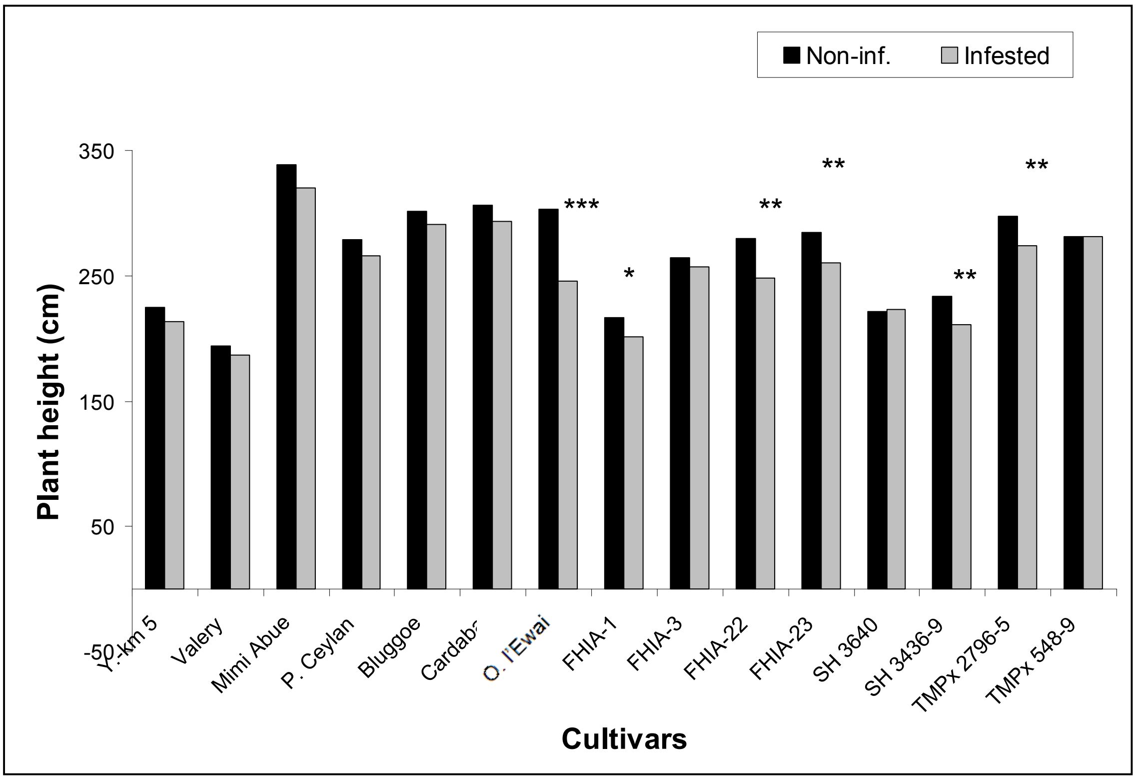

Figure 3. Plant height (cm) at flowering of banana and plantain cultivars in nematode-infested and non-infested plants of banana (*Musa* spp.) in a field trail in southeastern Nigeria.

***, *** indicate that means are significant different to the control (non-infested plot) according to Student's t-test at P ≤ 0.05, P ≤ 0.01, and P < 0.001, respectively*

Table 4. Eigenvectors, eigenvalues, proportions and cumulative proportions of principal components of the root damage indices at flowering of banana (*Musa* spp.) in a field trail in southeastern Nigeria.

	Prin1	Prin2	Prin3
R. similes	-0.418	-0.270	0.255
H. multicinctus	0.002	0.602	0.444
H. dihystera	0.002	0.559	-0.496
Hoplolaimus	0.492	-0.234	-0.294
Melodoigyne	0.379	0.125	0.617
Dead roots (%)	-0.462	0.351	-0.129
Necrosis index	0.475	0.240	-0.089
Eigen value	2.646	1.724	1.167
Proportion	0.378	0.246	0.167
Cumulative proportion	0.378	0.624	0.791

Harvest

Mimi Abue and Pisang Ceylan had high numbers of *R. similis*, while FHIA-23 and SH 3436-9 had very low numbers in the plant crop (Table 5). Mimi Abue was a very good host for *H. multicinctus* with over 24,000 nematodes per 100 g fresh roots. The densities of *H. dihystera, Hoplolaimus* and *Meloidogyne* were relatively low for all cultivars. The results show consistency across both cycles.

The root necrosis index and percentage of both dead roots and rhizome lesions were highest for Valery and Mimi Abue in the plant crop. Root necrosis was lowest for Yangambi-km 5 and SH 3640. The percentages of dead roots were low for Yangambi-km 5 and Pisang Ceylan in both plant and ratoon crop (Table 5).

The average bunch weight of the nematicide-treated block was 11.1 kg, which was significantly higher than in the infested field (8 kg), resulting in an overall bunch weight reduction of 29% due to the prevailing nematodes in this experimental field. Bunch weight was significantly reduced in Yangambi-km5, Valery, Bluggoe, FHIA-22, FHIA-23, SH 3436-9 and TMPx

2796-5 (Table 6). Toppling occurred mostly in the cultivars Valery, Obino l'Ewai, Mimi Abue, TMPx 2796-5 and TMPx 548-9 (Figure 5). The bi-plot (percentage of bunch weight reduction versus toppling in infested plots) allowed to explain why the differences of bunch weight of susceptible plantains Obino l' Ewai and Mimi Abue and the plantain hybrid TMPx 548-9 between non-infested and infested plots were not significant, although higher than that recorded for Yangambi-km5. The number of plants bearing bunches was significantly lower in the former cultivars vis-à-vis Yangambi-km5, which led to this confusing statistical result.

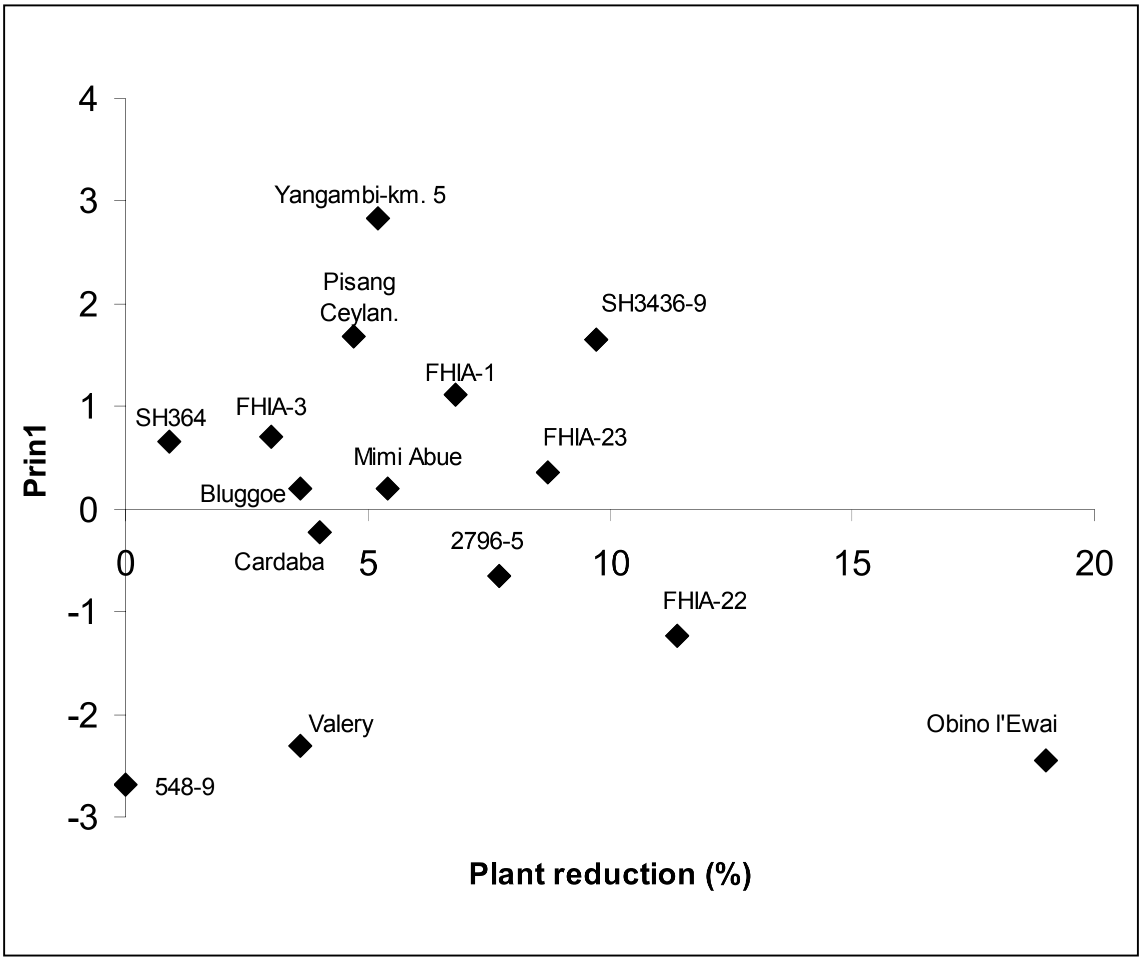

Figure 5. Bi-plot of bunch weight reduction versus plant toppling. Percentage as per losses and toppling in infested vis-à-vis non-infested of banana (*Musa* spp.) in a field trail in southeastern Nigeria.

Table 5. Nematode densities in 100 g roots, root necrosis, percentage dead roots and percentage rhizome lesions at harvest, compared to the non-infested plot for the different cultivars of banana (*Musa* spp.) in a field trail in southeastern Nigeria.

Cultivar	Root necrosis	Dead roots	Rhizome lesions	*R. similis*	*Hoplolaimus*	*H. multicinctus*	*H. dihystera*	*Meloidogyne* spp.
A. Plant crop								
Yangambi-km 5	12*	6	3	2,413$^{\Phi}$	328	8,044$^{\Phi}$	3,559*	2,417
Valery	39$^{\blacktriangledown}$	38$^{\blacktriangledown}$	11$^{\blacktriangledown}$	9,397*	361	9,403$^{\blacktriangledown}$	5,319	3,125
Mimi Abue	38	39$^{\Phi}$	15$^{\blacktriangledown}$	18,917	0	24,583$^{\Phi}$	9,717$^{\blacktriangledown}$	6,000
Pisang Ceylan	7	1	2	10,319	125	6,111*	667	8,083
Bluggoe	24$^{\Phi}$	21$^{\blacktriangledown}$	9$^{\blacktriangledown}$	1,995*	622	13,274$^{\blacktriangledown}$	6,907*	3,338
Cardaba	25$^{\blacktriangledown}$	23$^{\Phi}$	8$^{\Phi}$	2,274$^{\Phi}$	328	8,044$^{\Phi}$	3,559*	2,417
FHIA-1	15$^{\blacktriangledown}$	13*	2*	1,255	270*	7,687$^{\blacktriangledown}$	1,703*	3,625$^{\blacktriangledown}$
FHIA-3	17$^{\blacktriangledown}$	14	2*	1,005	514	6,815*	1,412$^{\Phi}$	3,301
FHIA-23	26*	7	3	27	416	9,903$^{\blacktriangledown}$	10,458*	3,035
SH 3640	10$^{\Phi}$	7*	3	4,263$^{\Phi}$	184	5,475$^{\Phi}$	1,413$^{\Phi}$	2,325
SH 3436-9	25$^{\Phi}$	5	9	30	1,042$^{\Phi}$	12,792$^{\blacktriangledown}$	10,054$^{\Phi}$	4,238$^{\Phi}$
TMPx 2796-5	25$^{\Phi}$	18*	4*	2,462*	307*	8,301$^{\Phi}$	2,968$^{\Phi}$	2,494
TMPx 548-9	25$^{\blacktriangledown}$	22$^{\Phi}$	7$^{\Phi}$	8,866$^{\Phi}$	307*	8,301$^{\Phi}$	2,968$^{\Phi}$	2,494
B. Ratoon crop								
Yangambi-km 5	14$^{\Phi}$	9	12*	2,433$^{\blacktriangledown}$	650	10,162$^{\blacktriangledown}$	3,900$^{\blacktriangledown}$	5,433$^{\Phi}$
Valery	27*	51$^{\Phi}$	22*	29,250$^{\blacktriangledown}$	214	9,928$^{\blacktriangledown}$	7,167$^{\blacktriangledown}$	2,012
Pisang Ceylan	17	8	6	4,083*	146	8,948$^{\Phi}$	6,031$^{\Phi}$	2,812
Bluggoe	30$^{\Phi}$	24$^{\blacktriangledown}$	30$^{\blacktriangledown}$	4,300$^{\blacktriangledown}$	34	8,700	2,997	2,403
Cardaba	26$^{\blacktriangledown}$	34$^{\blacktriangledown}$	15	5,014$^{\blacktriangledown}$	521	10,326$^{\blacktriangledown}$	5,875$^{\Phi}$	2,653
FHIA-1	19$^{\Phi}$	17$^{\Phi}$	16	2,019*	569	9,199$^{\Phi}$	3,815$^{\blacktriangledown}$	4,366
FHIA-3	23$^{\blacktriangledown}$	12$^{\Phi}$	23$^{\Phi}$	572	494	15,533$^{\blacktriangledown}$	3,683	5,028
FHIA-23	21*	9	10	437	465	17,187$^{\blacktriangledown}$	4,972$^{\Phi}$	4,639
SH 3640	21$^{\blacktriangledown}$	14*	16	1,792	620	11,143$^{\blacktriangledown}$	3,106$^{\blacktriangledown}$	3,801
SH 3436-9	24*	10	10	1,922	880	10,698$^{\blacktriangledown}$	6,583$^{\blacktriangledown}$	3,385
TMPx 2796-5	26$^{\blacktriangledown}$	21*	14$^{\Phi}$	2,061	507	18,462$^{\blacktriangledown}$	3,121*	3,417
TMPx 548-9	23*	60$^{\blacktriangledown}$	26*	6,292	139	11,278	7,861	2,764

*, $^{\Phi}$, $^{\blacktriangledown}$ indicate that means are significant different to the control (non-infested plot) according to Student's t-test at $P \leq 0.05$, $P \leq 0.01$, and $P < 0.001$, respectively

Table 6. Bunch weight (BW, kg plant^{-1}) in nematode-infested and non-infested banana (*Musa* spp.) in a field trail in southeastern Nigeria.

Cultivar	BW infested	BW non-infested	Bunch weight loss (%)
Yangambi-km 5	6.5	8.5	- 23 *
Valery	4.6	9.7	- 53 *
Mimi Abue	7.6	10.9	- 30
Pisang Ceylan	9.1	9.0	0
Bluggoe	3.6	6.5	- 45 *
Cardaba	7.2	6.6	(+ 9)
Obino l'Ewai	6.9	9.5	- 27
FHIA-1	10.9	13.8	- 21
FHIA-3	13.8	16.3	- 15
FHIA-22	7.6	14.1	- 46 *
FHIA-23	6.6	9.6	- 31 *
SH 3640	11.2	13.2	- 15
SH 3436-9	7.2	13.3	- 46 *
TMPx 2796-5	8.4	12.2	- 31 *
TMPx 548-9	8.4	12.7	- 34

** indicates that bunch weights between infested and non-infested plots was significantly different according to Student's t-test at $P \leq 0.05$*

Discussion

Comparing nematode density, root trait records, plant height and bunch weight among cultivars in infested and non-infested plots, they can be rated as per their host plant resistance or tolerance to the prevailing nematodes in this experimental site in southeastern Nigeria. For example, the cultivars TMPx 548-9, Yangambi-km 5, Bluggoe, Cardaba and SH 3640 showed the same response to nematode infestation at pre-flowering and flowering. However, the dessert banana Valery had a significant different plant height between infested and non-infested plots at pre-flowering but not at flowering because the plants heavily infested plants with *R. similis* died by the time of flowering. At flowering, only the strongest plants survived and plant height of only those plants was taken, which explains that plant height did not differ significantly between infested and non-infested plots for this cultivar. Such a result illustrates the importance of monitoring the trials and recording the data throughout the crop cycle.

Plant height between infested and non-infested plants was significantly reduced at the 17% threshold before flowering (Fig. 1). The cultivars SH 3640, Yangambi-km5 and FHIA-23, which showed low damage due to nematodes and did not reduce significantly their plant height, may be therefore rated as resistant to nematode infestation at this development stage. Such results also confirm a previous report by Sarah *et al*. (1992), who indicated that Yangambi-km5 showed resistance to *R. similis* in greenhouse experiments. Similar results were found in field trials (Price, 1994: Fogain and Gowen, 1998). Bluggoe, Cardaba and TMPx 548-9 showed non-significant plant height reduction in infested plots viz. a viz. the non-infested plants. The root damage, however, was significantly different between the infested and non-infested plants (Table 2). These cultivars can be thus rated as tolerant to nematode infestation. The remaining cultivars had a significant plant height reduction when comparing the nematode-infested with the non-infested plots. Furthermore, 'FHIA-1', 'FHIA-22', 'TMPx 2796-5', 'Obino l'Ewai' and 'Valery' showed a high damage index and a high reduction in plant height and can be rated as susceptible to nematode infestation.

Cardaba and Pisang Ceylan did not show significant losses when comparing bunch weights between infested and non-infested plots (Table 6). Furthermore both triploids along with the tetraploid hybrids FHIA-3 and SH 3640 showed a low toppling rate (Figure 5). The AAB dessert banana Pisang Ceylan also showed non-significant root damage (in both crop cycles) or *R. similis* densities (in the plant crop) in the infested plots (Table 5), which suggests that this triploid cultivar may be regarded as partially resistant to this nematode. Similarly, the triploid ABB cooking banana cultivar Cardaba with significant root damage and densities of both *R. similis and H. multicinctus* may be regarded as tolerant to nematode infestation, which could account for the lack of bunch weight loss in the infested plots. The tetraploid cooking banana hybrid FHIA-3 may be also regarded as resistant to *R. similis* as shown by its non-significant densities for this nematode in both crop cycles.

The results of this field experiment complement previous assessments from our research team about sources of resistance to *R. similis* in East African and Asian banana germplasm (Dochez *et al.* 2005, 2006). The individual root inoculation method (Dochez *et al*., 2000; De Schutter *et al*., 2001) was, however, used for screening the *Musa* accessions for resistance to *R. similis* in both experiments.

Acknowledgements

Financial support by the Flemish Organization for International Co-operation and Technical Assistance (VVOB: Vlaamse Vereniging voor Ontwikkelingssamenwerking en Technische Bijstand) and the Directorate General for International Co-operation (DGIC, Belgium) is gratefully acknowledged. The authors wish to thank Mr. Idowu Rotifa for helping with the data collection and IITA Tissue Culture Lab at the High Rainfall Station (Onne, Nigeria) – led by Dr. Jonathan H. Crouch – for providing the planting materials.

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CONTRIBUTION OF LOCAL AGRICULTURAL SYSTEMS IN CONSERVATION OF PLANT GENETIC RESOURCES IN CENTRAL ALBURZ REGION / IRAN

Korous Khoshbakht, Leila Tabrizi, Abdolmajid Mahdavi Damghani

Abstract

Explorations for plant genetic resources were undertaken at 20 sites including homegardens and small fields in the central Alburz region located in Northern Iran during the years of 2007 and 2008. Agricultural and horticultural plant species of the area were surveyed. The establishment of an effective program for maintenance of plant genetic resources comprises germplasm management *ex situ*, *in situ* and *on-farm*. More than 86 species of cultivated plant species could be indicated for this area. Our results revealed that the studied area is suitable for the domestication of wild species within to local agricultural systems.

Key words:
Agrobiodiversity, Checklist, Domestication, Homegarden, In situ, On-farm

Introduction

A local agricultural system refers to an agricultural ssetting in which food is produced and marketed locally. It tends to be small in size and more divers in crop species than other systems. Such a system can effectively enhance the economic and environmental quality as well as contribute to the in conservation of local crop germplasm (Wilken 1987, Beets 1990, Altieri 1995, Uphoff and Altieri 1999).

Agricultural systems comprise conventional (industrial) and traditional (local) agricultural systems. Most conventional agroecosystems are characterized by intensive application of *off-farm* inputs, mainly synthetic agrochemicals and mechanization as well as large scale monoculture in order to maximize short term yield without considering long-term consequences

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on the sustainability of agricultural and natural ecosystems (Mahmoudi et al., 2008). Traditional agroecosystems are mostly small farms managed by small-holder farmers in which application of *off-farm* inputs is lower than in conventional farms. One of the main characteristics of these local agricultural systems is a diverse range of crops to supply farmers' family demands that has led to the increase in the overall biodiversity of these agroecosystems (Khoshbakht et al. 2006, Kamkar et al. 2007).

Botanical checklists are useful tools for research on cultivated plants (Hammer 1990) and the specific methods are described elsewhere (Hammer 1991). The checklist allows a characterization of the state of plant genetic resources in a given area. Although the checklists are often used for area surveys of wild plants, cultivated plants are included in some cases. A printout of the checklist can be used in future field works, or for the management of plant genetic resources and the exchange of information between interested persons and organizations.

Materials and Methods

The Central Alburz region with its semi-humid climatic conditions, cold winters, and warm summers is a part of the Hyrcanian biomes and located in Southern part of Caspian Sea (Khoshbakht and Hammer 2005). Broadleaf forests cover the main part of the area and agriculture and animal husbandry are main rural activities. In this region, the main cultivated crops are rice, wheat, barley, vegetables and citrus trees especially in the low lands.

Fieldwork was carried out in 2007 and 2008 to explose local agricultural systems including homegardens and small field at 20 different sites (Table 1). To obtain a quick insight into the crop plants of this area, the checklist method (Hammer 1991) was used. This method has been previously employed in other parts of the world, such as in Libya (Keith 1965, Hammer and Perrino 1985, Hammer et al. 1988), Cuba (Esquivel et al. 1989, 1992a, 1992b Hammer et al. 1989a), Korea (Hoang et al. 1988, Hammer et al. 1989b, Hoang et al. 1997), Southern Italy and Sicily (Hammer et al. 1990, 1992), North and central of Italy (Hammer et al. 1999a), Ustica; Italy (Hammer et al. 1999b) and Oman (Hammer et al. 2004).

All cultivated plants of the area were included with the exception of ornamental and forest plants, which have no agriculture and horticultural use. The inclusion of the plants into the list follows the same principles as the Mansfeld-List (Schultze-Motel 1986, Hanelt and IPK 2001).

Table 1: Geographical characteristics of different sites

Sites	Longitude (N) ..° ..′	Latitude (E) ..° ..′	Altitude (m asl.)
Shirdar-kala	36 23	42 45	190
Kati-lateh	36 21	52 51	280
Shirjeh-kala	36 19	52 52	280
Alam-kala	36 14	52 49	345
Sorkh-kala	36 12	52 56	400
Outo	36 04	53 01	570
Bahmanan	36 13	52 59	610
Pasha-kala	36 12	53 02	612
Shir-kala	36 19	52 52	700
Esas	36 09	53 04	900
Folowrd	36 04	53 08	1160
Arataban	36 03	52 56	1200
Zangeyan	36 04	52 56	1300
Karmozd	36 03	52 53	1320
Anarom	36 02	53 10	1460
Tilem	36 02	52 57	1550
Paland	36 10	52 57	1550
Alasht	36 04	52 50	1670
Bayeh-kala	36 02	53 07	1800
Lind	36 05	52 53	1890

Results

More than 86 species of cultivated plant species belongs to 23 plant families were identified (Table 2).

Table 2: Index of plant families and genera In small scale farming systems of the Central Iranian Alburz mountains in 2007/2008.

The plant families represented are given in alphabetical order. For each family, the genera represented are also listed alphabetically. The number of species per family or genus is given in brackets, except for case of one species per family or genus. Infraspecific taxa are not considered in the counts.

Family	Taxa
Actinidiaceae	- *Actinidia*
Alliaceae (5)	- *Allium* (5)
Asteraceae(2)	- *Helianthus*, *Lactuca*
Apiaceae (8)	- *Anethum*, *Apium*, *Coriandrum*, *Daucus*, *Eryngium, Foeniculum*, *Heracleum*, *Petroselinum*
Boraginaceae	- *Borago*
Brassicaceae (4)	- *Brassica* (2), *Lepidium*, *Raphanus*
Chenopodiaceae (2)	- *Beta*, *Spinacia*
Corylaceae	- *Corylus*
Cucurbitaceae (3)	- *Cucumis*, *Cucurbita* (2)
Fabaceae (11)	- *Cicer*, *Lens*, *Medicago*, *Phaseolus* (3), *Pisum*, *Trifolium, Trigonella*, *Vicia, Vigna*
Ebenaceae (2)	- *Diospyros* (2)
Juglandaceae	- *Juglans*
Labiatae (5)	- *Dracocephalum*, *Mentha* (3), *Ocimum*
Moraceae (3)	- *Ficus, Morus* (2)
Oleaceae	- *Olea*
Pedaliaceae	- *Sesamum*
Poaceae (9)	- *Hordeum*,*Oryza*, *Panicum*, *Saccharum*, *Setaria, Sorghum*(2), *Triticum*, *Zea*
Punicacea	- *Punica*
Rosaceae (14)	- *Armeniaca*, *Cerasus* (2)*, Cydonia*, *Eribotrya*, *Fragaria* (2), *Malus*(2), *Persica, Prunus* (3), *Pyrus*
Rutaceae (5)	- *Citrus* (5)
Salicaceae	- *Salix*
Solanaceae (4)	- *Capsicum, Lycopersicon*, *Solanum* (2)
Vitaceae	- *Vitis*

Discussion

To our knowledge, the present study is the first one carried out in this area. Several local cultivars of *Allium sativum*, *Lens culinarus*, *Oryza sativa*, *Punica granatum* and *Spinacia oleracea are* still are under cultivation. But also evidence for genetic erosion was observed in this area with the replament of landraces and local cultivars with new inbred cultivars. Therefore, an establishment of an effective program for the maintenance of plant genetic resources (PGR) is necessary. This program should comprise an *ex situ*, *in situ* and *on farm* component (Khoshbakht and Hammer 2004, Maxted et al. 2002).

Landraces in many crops have been identified as the most threatened category of genetic resources and are also the primary object of demands for compensation (Fowler and Mooney 1990, Hawkes 1983). They are the initial targets of conservation, and maintenance of these accessions of crop varieties in genebanks and botanical gardens (*ex situ* conservation) is useful to protect them from extinction. In this study part from landraces, cultivated plants even at the species level have been identified at different stages of extinction (Hammer and Khoshbakht, 2005). *Ex situ* conservation methods serve as a necessary backup for PGR. *In situ* conservation is not a new idea bur one which has re-emerged after successful *ex situ* conservation (Zeven 1996). As the conservation of crop genetic resources has progressed, conservationists have concluded that *in situ* conservation is needed to complement genebanks and botanical gardens. It also covers types of genetic resources that cannot be protected in genebanks, such as crops that show recalcitrance to off-site conservation (Hammer et al. 1996), as well as local knowledge and ecosystem interactions (Brush and Stabinsky 1996, Oldfield and Alcorn 1987). *In situ* conservation not only preserves genes for crop improvement but complex evolutionary processes, which will yield new germplasm in the future (Brush 1995).

On-farm management of PGR is a relatively new concept. There have been early proposals, by Kuckuck (1974), for the conservation of cereals fields together with wild relatives allowing genetic interchange in gene centers. However, only in the eighties of the last century was a broader attention given to on-farm conservation. A proposal, to conserve fields of einkorn (*Triticum monococcum* L.) and emmer (*T. dicoccon* Schrank) in Southern Italy (Perrino and Hammer 1984) and proposal to make the island of Linosa / Italy a center for on-farm conservation of plant genetic resources (Hammer et al. 1997) are some examples of efforts for on-farm management of PGR.

Other examples refer to tropical and subtropical areas, especially to centers of diversity of cultivated plants (Altieri and Merrick 1987, Esquivel and Hammer 1989, Brush 1989).

To establish such programs some practical and scientific problems have to be solved. Economic attractiveness to local farmers and ways to guarantee the genetic integrity of landraces and related management should be considered (Hammer et al. 1997, Maxted et al. 2002). Genebanks should be integrated in these programs to guarantee the conservation of rare and endangered species (Hammer 1999, Hammer et al. 2003).

The Alburz mountain region has suitable conditions for the domestication of wild species and their incorporations into local agricultural system. Homegardens provide a good environment to study evolutionary processes of plant selection as people adapt plants to new and changing conditions. Plant diversity depends upon agroecological conditions and socioeconomic aspects of gardeners (Khoshbakht et al. 2006).

Cultivation and semi-cultivation of wild fruits and shrubs such as *Berberis* sp., *Crataegus* sp., *Cydonia oblonga* Mill., *Diospyros lotus* L., *Ficus carica* L., *Malus orientalis* Ugl., *Mespilus germanica* L., *Prunus cerasifera* ssp. *macrocarpa* Erëmin & Garkov, *Prunus spinosa* L., *Punica granatum* L., and *Rubus* sp. was observed in homegardens of this area (Khoshbakht and Hammer, 2005). They have an important role in supplementing other foods. Collection of wild foods from uncultivated lands may add significantly to the food security of poor rural households (Guijt et al. 1995). Cultivation of some of these gathered wild species such as *Allium paradoxum* (M. B.) G. Don and *Eryngium caucasicum* Trautv. were started in a few homegardens (Khoshbakht and Hammer, 2006). This experimental cultivation is a first step for the domestication of these species. Evolutionary relations between wild and cultivated plants in the area have been observed and are in need of further studies.

Acknowledgement

This research was financially supported by a grant from Shahid Beheshti University. The authors express their gratitude to the vice-presidency for research and technology for its support.

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EARLY STUDIES ON MEIOTIC CHROMOSOMES AND THE PARADIGM SHIFT IN THE GERM-PLASM CONCEPT

A.T. Szabó

Dedicated to the memory of Rédei P. György (1921-2008), a pioneer of Arabidopsis germ-plasm research.

Abstract

The cradle of (cyto)genetics and the germplasm concept is in Central-Europe, in a relatively small geographical area situated now in Hungary (Keszthely/Kőszeg, Festetics 1819), Czech Republic (Brünn, Mendel 1865), Austria (Wien and Graz, Correns 1900, Tschermak 1900) and in different cities situated in Germany (Strasburger 1877; Weismann 1883, 1885; O Hertwig 1876, 1909; R. Hertwig 1889, 1902; Correns 1900, 1902; Boveri 1887, 1889, 1904; Goldschmidt 1911, etc.).

This paper deals with a neglected aspect of the paradigm shift in early germplasm studies: the cytogenetic discoveries of Gelei József. Gelei was an assistant of the influential histobiologist Apáthy István who sent him between 1912-1913 to R. Hertwig and R. Goldschmidt in Munich and to Th. Boveri in Würzburg. Gelei was able to demonstrate the dynamics of chromidiums (now named DNS and RNS) in the nucleus and through the nuclear membrane and the strictly homologue pairing of chromosomes. He vindicated for the first time the full length pairing of the homologues in meiosis, described correctly the phenomenon of chromosome interlocking – "*an aspect of chromosome behavior whose significance has only recently been reappreciated*" (Rasmussen 1976 ap. Rédei 2003, Jones and Croft 1989), observed the micro-nucleation during irradiation of gametic mother cells with radium bromide and proposed *Dendrocoelum lacteum* as a model organism for cytogenetic (meiosis) studies. His reports on chromosome pairing became classical papers of cytogenetics (Gelei 1921, 1921a, b, 1922; Jones and Croft 1989).

The fate of the genetic life work of Gelei was strongly influenced by external conditions: the disintegration of the Austro-Hungarian Empire (1920), the scientific language shift from German to English, the Second World War (1940-1944), and between 1946-1976 the lasting influence of Lysenkoism. The paper examines the reasons of the late rediscovery of Gelei's works especially in his homelands (Hungary, Romania) and the role of the Unitarian religion in this process.

The discussed topics are of general interest for paradigm shift research, history of science and that of scientific ideas, including the evolution of the (American) germplasm concept to a (general) germplasm concept, genetic resource research and the conservation of the (agro) biodiversity (Hammer 1998, 2001, 2003, 2003a, Hammer and Teklu 2008 etc.).

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Key words:
Apáthy, Boveri, Gelei, Goldschmidt, Hertwig, cytogenetics, chromosomes, interlocking, radio-genetics (micronucleation), germplasm concept, Lysenkoism, science and religion, science history

Introduction

Gelei József was a Transylvanian Hungarian geneticist and protistologist, student and assistant of the influential histologist, biologist, sociologist and politician Apáthy István, professor at the University of Kolozsvár[1]. Apáthy was familiar with the results of O. and R. Hertwig, R. Goldschmidt, Th. Boveri and other German cytologists and sent the young Gelei to work in Munich and Würzburg in 1912-1913.[2] This stay yielded important results for chromosome science and influenced the evolution of germplasm theory too, but the results of Gelei in genetics were neglected even in his home countries Hungary and Romania. Surprising genetic "rediscoveries" occurred regularly in these countries. For the rediscovery of the earliest "*Genetic Laws of Nature*" almost two centuries were needed. Yet we know, that these early "laws" were formulated in Brünn (now Brno, Czech Republic) during a theoretical debate on technical terms used in plant and animal breeding. Discussions about the role of the environment in heredity (that is during a "*Nature vs. Nurture*" debate) culminated in the recognition that there is an *internal (genetic) environment, basically different from the pre-*

[1] **Locality names**: a single locality mentioned in this paper has both an English and German name (Munich = München) – in the English text the English name is used; Würzburg has only a German name; Kolozsvár has many names: before 1920 and under Austro-Hungarian rule in Hungarian texts Kolozsvár, in Latin texts Claudioplis, in German Klausenburg and in Romanian Cluj, (newly Cluj-Napoca); the name Kolozsvár is used here for traditional Hungarian, the name Cluj for the traditional Romanian and the name Cluj-Napoca for the actual situations.
Technical (cyto/genetic) terms in this paper are mostly in the form and meaning used in the first quarter of the 20th century. In case of germplasm the orthography of the first American translation is followed in some cases for historical reasons.
Names: the sequence of the family and given names in this paper follows the logic of different national languages, that is in the case of Hungarian names the "Hungarian citation" (family name first).
The orthography of the text follows the rules of US English.

[2] Oskar Hertwig (1849-1922) was mainly a protistologist in Jena and Berlin, was instrumental also in animal oogenesis (especially on *Ascaris*) beginning with 1875, wrote monographs on nucleus research (1909) and animal organization (1922); his younger brother Richard Hertwig (1850-1937) was evolutionist and close friend of Ernst Haeckel, worked also on protists (especially on *Paramecium*, 1889), later on oogenesis (1902) and comparative cytology. Richard Goldschmidt (1878-1958) became assistant of R. Hertwig in 1903, wrote his first (still influential) works on genetics (1911, 1915) and sex determination (1929, in Berlin), much later wrote a "*Theoretical Genetics*" (1955) as an US citizen . Theodor Boveri (1862-1915) was an assistant of R. Hertwig (between 1887-1893) thereafter he was professor in Würzburg; he was outstanding in cytogenetics and "gametology" wrote a series of influential papers on fecundation (1887, 1891) hybridization, chromosome research (1904, 1905), and even on oncology (1914) (cf. Jahn et al. 1982, Rieger et al. 1976, Sturtevant s.a.).

viously known (physiological) environment. It is of special interest, that these empirical laws were published in German language and exactly in Brünn were Mendel was active four decades later (Festetics 1819, Szabó and Pozsik 1989, 1990, Szabó 1997, Orel and Wood 2001). The discoveries of Festetich Imre were obscured by the political and economical problems of the Hapsburg Empire around 1848/1849 (De Candolle 1883, Szabó 1983, Orel and Wood 2001). *Mutatis mutandis* … something similar also happened to the discoveries of Gelei around 1919.

The rediscovery of the foundations of the factorial genetics lasted almost four decades (Mendel 1865, 1866, 1870; Correns 1900, 1902; Tschermak 1900, 1960; de Vries 1900). The international rediscovery of the importance of Theodor Boveri and his colleagues is still in progress (*http://www.biozentrum.uni-wuerzburg.de/index.php?id=thepersontheodor*; 090115szta; Stubbe 1965, Wolbert 2009).

August Weismann (1834-1914) and the role of his ideas about germplasm in the paradigm shift toward the new science of the (classical and molecular) genetic resource research still remains to be reconsidered in many respects. The emergence of the germplasm concept and the "chromosome-science" and "gene-theory" (Weismann 1883, 1885 German editions; and the American edition (1892/1893), followed quickly by the first Plant Introduction (PI) number in the USA Seed and Plant Introduction Section (1898); the works of Sutton (1903), Morgan (1910), Morgan and Cattell (1912); Johannsen (1909, 1926), as well as the periodic raise and fall of the genetic resource research are perhaps the most spectacular cases of the interference of science with politics, ideology and economy (Vavilov 1911-1913, 1939, 1968 cf. Vavilov 1992; Lysenko 1948; Watson and Crick 1953; Dubinin 1975; Sinskaia 1991; Rio Conference on Biodiversity 1992. For further details cf. Hawkes 1994 see also Flittner 1995, Diamond 1997, Meinel 2008).

The most representative figure of the practical germplasm science, that is the modern genetic resource research was Vavilov (1887-1943). He and his ideas were sentenced to death in a large part of Europe and Asia between 1938-1975 (Dubinin 1975).

In the following sections the significant contributions to the paradigm shift in (cyto)genetics related to the correct interpretation of the germplasm concept, based on experimental studies carried out in Kolozsvár, Münich and Würzburg by Gelei József are discussed. These studies were influential among leading German cytologists of the time, but – except some authors such as Szabó (1938) – have been largely neglected later both in Hungarian, Romanian and international science (Rapaics 1952, Raicu and Nachtigal 1969, Giosan and Săulescu 1969, Dohy 1999, Velich 2001; Rédei 1987, 2003, Weaver and Hedrick 2000).

The political and ideological backgrounds of Gelei's neglect (changes in political boundaries and in ideology) are quite obvious. But there is another aspect, which is treated in science history textbooks even more "chastely" than the influence of politics and ideology on science history: the often overlapping religious and ethnic aspects. The "Gelei-case" demonstrates that religious and ethnic aspects may also influence scientific "objectivity". In this particular case the fact that Gelei József was an active Unitarian – which is an almost exclusively Hungarian church in Transylvania – is especially interesting. The Unitarian Church is one of the most deeply reformed churches. This religion spread over the world in the 16th century mostly from Transylvania – even up to England and the United States. The Wedgwood-Darwin family was in part also Unitarian – which may be of interest for better understanding of another great paradigm shift in science: the emergence of the selection theory (Darwin 1859) developed parallel with the emergence of genetics (Festetics 1819 – rediscovery in 1989; Mendel 1865 – rediscovery in 1900).

From a theoretical point of view and for a better understanding of the European science history it is also of interest that among the Transylvanian Hungarians the appreciation of Gelei József is based more on non-scientific, religious and ethnic grounds (references in the Hungarian version of this paper, Szabó 2009 in press).[3] A description of the hidden conflicts – heavily burdened by nationalistic loads – between the very conservative Orthodox church (the "state church" of Romania) and the scientifically open minded Protestant Unitarian church would be far beyond the scope of the present paper. The same holds for an assessment of the influence of the Catholic church on the Hungarian science history, such as the emergence and later interpretation of protestant pharmacobotany and herbalism.

Materials and Methods

Five letters ("scientific reports") written partly by Gelei from the Hertwig's and Goldschmidt's laboratories in Munich and from Theodor Boveri's laboratory in Würzburg to his professor Apáthy in Kolozsvár, and two answers (drafts) of Apáthy to Gelei – all written in Hungarian – are summarised here in English. The first is dated 18th January 1912, the last is dated 24th October 1913 covering almost a 2-year period, as follows:

[3] In order to avoid any misunderstanding: the writer of these lines is not an Unitarian.

- ***1912, 18th January:*** *Gelei's report from Munich to Apáthy in Kolozsvár (Állattani Intézet)*
- ***11th February****: Apáthy from Kolozsvár to Gelei in Munich, (draft).*
- ***18th March:*** *Gelei from Munich to Apáthy in Kolozsvár*
- ***1913, 3rd March:*** *Gelei from Würzburg (Zoologisches Institut) to Apáthy in Kolozsvár*
- ***18th March:*** *Gelei from Würzburg (Zoologisches Institut) to Apáthy in Kolozsvár*
- ***25th March:*** *Apáthy from Kolozsvár to Gelei in Würzburg (draft)*
- ***24th October:*** *Gelei' report from Würzburg to Apáthy in Kolozsvár.*

A selection from the Apáthy-and-Gelei letters were published first in Hungarian by Szabó (1976) and are included also in the Hungarian version of this paper (Szabó 2009, in press). Here are just included some excerpts relevant for the development of the chromosome theory as an experimental proof for the Weismannian idea of germplasm.

The content of these letters can be correlated here with the printed cytogenetic publications of Gelei (1909/1912, 1913, 1914, 1920, 1921+a,b, 1922, 1923).

Results and Discussions

Who was Apáthy István and Gelei József ?

Apáthy István (Stefan/Stephan Apáthy, 1863-1922) became a medical doctor in 1885 in Budapest, worked for a period on the Zoological Station from Naples (1886-1888) were he got acquainted with the works of leading cytologists of the time such as O. and R. Hertwig, T. Boveri, T. Morgan and other scientists interested also in cytological aspects of heredity. Apáthy became famous after 1885 for his histological studies (Apáthy 1885, 1886, 1896, 1900 for further details see Nagy 1998). In 1890 Apáthy moved to the University of Kolozsvár, became the head of the Zoological Institute and rector of the university (1903-1905). Based on his experience in Naples Apáthy reorganized in 1909 the Zoological Institute, making it one of the most modern biological institutes of his time. After the political changes following the First World War, Apáthy was arrested and sentenced to death by the new Romanian authorities without any sound reason. The sentence was nullified in 1920 by the Romanians, but Apáthy never recovered and died in Budapest in 1922. These apparently non-scientific details illustrate the conditions during the chromosome studies of Gelei (1913, 1920, 1921, 1922, 1923).

Gelei József (Joseph/Josef Gelei, 1885-1952) was a Transylvanian Hungarian student of the Faculty of Natural Sciences in University of Kolozsvár, where he received a degree in biology and chemistry (1905), became assistant of Apáthy who sent him in 1906 to the University of Graz to work with L. Graff. He received his doctoral degree with a thesis in protistology written on a new *Turbellaria* species (1908), worked first as a suppliant and in 1919 – when the Hungarians lost their university chairs due to the political changes in Transylvania – he became a regular school teacher of the Unitarian College in Kolozsvár.

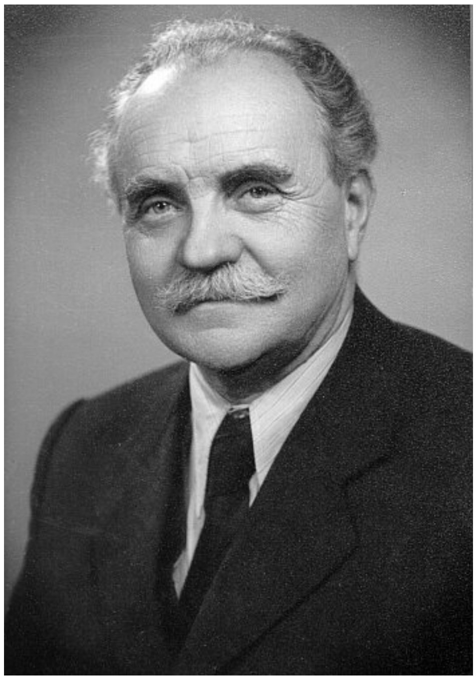


Fig. 1: József Gelei (1885-1952)
Source: Kelemen M. (2008) http://uninaplo.unitarius-halo.net/unitariuselet/files/2008/07/gelei-jozsef.jpg

Apáthy sent him in January 1912 to R. Hertwig in Münich and in 1913 to Th. Boveri in Würzburg.

Returning from abroad, in 1914 Gelei became professor of comparative cytology of the same Institute and served here until 1919. In 1920 the Hungarian University of Kolozsvár has been transformed into the Romanian University of Cluj. The Hungarian professors were forced to leave Romania; they founded a new university in Szeged (Hungary). Gelei followed this move, became a founding member of the University of Szeged, founder and head of the Dept. of General Zoology and Comparative Anatomy (1924-1940), dean of the Faculty of Mathematics and Natural Sciences (1929-30, 1935-36) and rector of the University (1937-38). In 1923 he was elected first as a correspondent, and in 1938 as a regular member of the Hungarian Academy of Science (HAS).

Between 1940-1944 Gelei returned with the new Hungarian administration to his home land, Transylvania, and participated in the reorganisation of the Hungarian University of Kolozsvár. In 1944 Gelei was forced to move to Budapest, losing again all his former institutional and personal background (institute, library, collections, documentation and personal correspondence). Still active, but in poor health Gelei was invited again to Szeged as head of the Biological Institute where he worked until his death (1952). A decade later, in 1962 F.B Straub, a fellow of Gelei in the Hungarian Academy of Science founded here the famous Biological Research Centre of HAS – based also on the students of the Gelei-school (http://www.szbk.u-szeged.hu/).

The political changes in this very sensitive area of Central Europe deeply influenced the main periods of scientific creativity of Gelei. Varga (1954) speaks about three life periods, neglecting (under ideological pressure) the "German-period" of Gelei (1912-13), his second Transylvanian period between 1940-1945, and the Lysenkoist period – all influencing Gelei's interest and his fate. According to us not three, but six main scientific periods can be identified in his career:

Between 1940-1944 Gelei returned with the new Hungarian administration to his home land, Transylvania, and participated in the reorganisation of the Hungarian University of Kolozsvár. In 1944 Romania turned to Soviet Union, the whole front collapsed and Gelei was forced to move to Budapest, losing again all his former institutional and personal background (institute, library, collections, documentation, personal correspondence etc.). Still active, but in bed health Gelei has been invited again to Szeged as head of the Biological Institute where he worked until his death (1952). A decade later, in 1962 F.B Straub, fellow of Gelei in HAS founded here the famous Szeged Biological Research Centre of HAS (http:// www.szbk.u-szeged.hu/).

The political changes in this very sensitive area of Central Europe determined also the main periods of scientific creativity of Gelei József.

Varga (1954) speaks about three life periods, neglecting (under ideological pressure of the "proletarian internationalism" the second Transylvanian period of Gelei, between 1940-1945, the German-period (1912-13), and the lysencoist period. According to us not three, but six main scientific periods formed his career:

1. The first period began in 1905 and ended in 1912 with studies on *Turbellaria* and a monograph on the histology of *Dendrocoelum lacteum*.
2. The second "genetic period" (1912-1913) was the "German period" leading Gelei to the study of the oogensis, meiosis, and the hereditary role of the chromosomes. These results contributed substantially to the paradigm shift from the id-concept towards the chromosome theory.
3. The third period is the one between his return from Germany to Kolozsvár (his nomination as professor of the University in 1914) and the end of the First World War (1920). In this period Gelei became a very active scientist and a successful professor both on graduate and undergraduate level. As an active member of the Erdélyi Múzeum Egyesület (Transylvanian Museum Society) in Kolozsvár, which was the owner of all museum collections of the University, Gelei also became the curator of the zoological collections here.

4. The fourth period began after the First World War, in 1920 in Szeged (even if his “genetic” monographs were published just after the war in 1921, 1922 and 1923). Between 1925 and 1940 a clear shift in Gelei’s interest occurred. This was the most prolific period of his life, overwhelmed with administration, teaching and research focused on zoology, comparative histology, protistolgy, hydrobiology, studies on the morphology, taxonomy and physiology of protozoa (movements of cilia and the structure and function of the neuronema in protozoa). Gelei participated also in the study of protozoa of Lake Balaton (Plattensee)..
5. The fifth short period is his second Transylvanian activity phase between 1940-1945. This was again a new beginning in research, teaching and administration.
6. The last is his second period in Szeged (1945-1952). At first he was only a “delegated professor” teaching medical biology, working again under very modest conditions, lacking even a microscope of his own. This new beginning was perhaps the most difficult – under permanent ideological control and suspicion. Thanks to the Hungarian Academy of Science (HAS) Gelei restarted his protistological studies focusing on the living communities of small waters (springs, wallows, paddles, plashes and ponds) and describing a series of new genera and species of *Ciliata* . This time he was lucky not to work with genetics in this dark era of Lysenkoism, when his earlier works on chromosomes were sentenced to elimination from almost all libraries of Hungary including the central library of HAS in Budapest.

The influences of non-scientific factors on Gelei’s scientific life are very similar to that of his master – Apáthy István – whose fate was surely a life lesson for Gelei. But he never mentioned these non-scientific aspects in his autobiography, excluding perhaps science education:

> *"Tőle [Apáthytól] tanultam, hogy a természetbúvár életlényegét a hűséges megfigyelés és az igazságos közlés képezi. Haladásának alapfeltétele pedig az, hogy semmiféle eszköz nem tökéletes és senkinek a módszere sem befejezett: mindennel és mindig kísérletezzék. Tőle tanultam szellemet, módszert, tisztalátást, tudásbecsületet, háborúgyűlöletet, emberszeretetet. Róla ragadt rám a búvárszenvedély, éjnek nappallátétele, mert közös munka közben sokszor virradt ránk a hajnal a laboratóriumban."*

The English version:

> *“I learned from him [i.e. form Apáthy] that the essence of the life for a life scientist is the faithful observation and the truthful publication; the basic condition of progress in science is the discern-*

> *ment; there is no perfect instrument and nobody can create a fully perfect methodology, so experimentation with everything is always needed. I learned from him the spirit and the methods of science, clear vision, respect for knowledge, the hate of war, the love of our fellows, humanity and charity. I learned from him the love for research, the ability to work for day and night, because working together days were often breaking on us in the laboratory"*

(Varga, 1954; these lines are reproduced here first in his untranslatable Hungarian). The scientific atmosphere reflected in these lines explain in part also the question formulated in the first number of Nature (London) published in the second millennium: *"Why the twentieth century was made in Budapest?"* (Smil 2001).

The Essence and Impact of Gelei's Results on the Paradigm Shift in Germ-Plasm Concept

As a (cyto)geneticist Geleiwas beside Th. Boveri most productive in Würzburg. Here he was instrumental in documenting exactly and without doubt the genetic importance of the behavior of meiotic chromosomes during gametogenesis and consequently their outstanding similarity with the theoretical germplasm of August Weismann. Gelei also demonstrated the chromosomal mechanisms of meiosis, based on the similar knobbing patterns of the chromatida in the maternal and paternal, homologue pairs in early leptotene diploid germ cells. He explained correctly the mechanism and role of chromosome movements in the so called "bouquet stage" and pointed out the essence of this stage for the longitudinal pairing of the chromosomes – a fascinating research field even in the 21st century. Gelei documented also convincingly – even for Boveri (see his letter dated 3rd March 1913) the absolutely identical chromomeron pattern of *Dendrocoelum* chromosomes entering in homologue pairing of the maternal and paternal genetic material, and even the phenomenon of interchange between them – named by Morgan and Cattell exactly in 1912 as "crossing over". Using the Apáthy-methods modified by him according to the specific needs of meiosis studies, Gelei proved without doubt the full length pairing of the homologues in meiosis, described correctly the phenomenon of chromosome interlocking – "*an aspect of chromosome behaviour whose significance has only recently been reappreciated*" (Johnes and Croft 1989). He also described (in a private letter to Apáthy, dated 18th March 1913) micronucleation during irradiation of gametic mother cells with radium bromide – obtained directly from Röntgen – and foresaw the effects of this radiation on further generations. Gelei and Boveri were also the first ones to propose *Dendrocoelum lacteum* as a model organism for cytogenetic (meiosis) studies (Gelei 1913, and following publications).

Gelei's reports published in German (1922) and in Hungarian (1920/1921) became classical papers of cytogenetics (Johnes et Croft l.c.). Unfortunately, Gelei was not successful in convincing Boveri about the migration of trophic chromatin (named now mRNS) through the nuclear membrane.

The Documents: Excerpt from a Correspondence between Gelei and Apáthy

The documents supporting the above statements were presented in full length in print by Gelei in papers and monographs cited here in References, and in his correspondence with Apáthy edited first in 1976 and cited in full length in the Hungarian version of this paper written for the Memorial Volume on the 150th Anniversary of the Transylvanian Museum Society – Kolozsvár (Szabó 1976, 2009 in press). Here, just the main arguments are summarized as follows:

A: Letters from/to Munich

1. *Letter dated 18th Jan. 1912:* Gelei's first report from Munich, to Apáthy. (A handwritten letter dictated by Gelei to his wife.). Topics: departure from Budapest, living conditions in Munich, problems during the feasts, kind reception by Hertwig and Goldschmidt in the Zoological Institute, disappointment for the miserable conditions in which R. Hertwig and Goldschmidt conduct their teaching and research as compared to those in the Zoological Institute of Kolozsvár, a request for a microtom to be sent from Kolozsvár to Munich by Apáthy, difficulties in demonstration of the Apáthy-methods (for Goldschmidt's request) in these conditions, consultations with Kamenitz on cytological studies in Ascaris and Dendrocoelum; the work with the pre-prepared material brought with him from Kolozsvár, postal address of Gelei in Munich – Alte Academie, Reinhauser Strasse).
2. *Letter dated 11th Febr. 1912 (Apáthy to Gelei, draft).* Topics: allusion to Gelei's dictated letter, note about the German working habits as compared with the Hungarian habits and the "Americanization" of Hungarian scientists, meditations abut sending or not sending the microtome requested by Gelei, financial problems, request for further research reports in the future.
3. *Letter dated 18th March 1912 (Gelei to Apáthy).* Topics: Thanks with regard of Apáty's intervention by Méhely in Budapest regarding a paper of Gelei prepared for publication (Gelei 1913?), arguing for a new technical term – neurofibrillum – introduced in science by Apáthy, the photocopies of the illustrations prepared for publication corrected according to advice of Goldschmidt; problems regarding the study of

"chromidiums" in oocytes, the behaviour of chromosomes and nucleoli during the different stages of the cell division including centrosomes, nucleolar dynamics, chromosomal structure; the problem of the generative and trophic chromatin (now: DNA and RNA) and the difference between them during meiosis (only the generative divides perfectly in halves), Goldschmidt's advice to continue such studies also in spermatogenesis, the lack of new study material, Goldschmidt's congratulations for the results, Goldschmidt gives up his scepticism on the genetic role of chromidia (chromatida) based on Gelei's evidences, scientific news from Oscar Hertwig regarding the retirement of Weismann and the scientific value of its proposed successors (Doflein, Boveri, Korschel, Hecker, Hesse, Speemann), the perspectives in Freiburg after the Weismannian period under Doflein, pecuniary and postal problems; notes on the traditional (Latin) and modern languages of science (German, English, French).

B: Letters from/to Würzburg

The year 1913 in which Gelei worked in Würzburg was toward the end of the most productive period of his master here, professor Theodor Boveri and after publications which proved to be absolute priorities in genetics (Boveri 1901, 1904, 1905, 1914). The content and the atmosphere of the letters indicate that Gelei was aware of this. Under this influence he started a cytogenetic papers and monographs in German and Hungarian (Gelei 1913, 1914, 1920, 1921, 1921a, 1922, 1923).

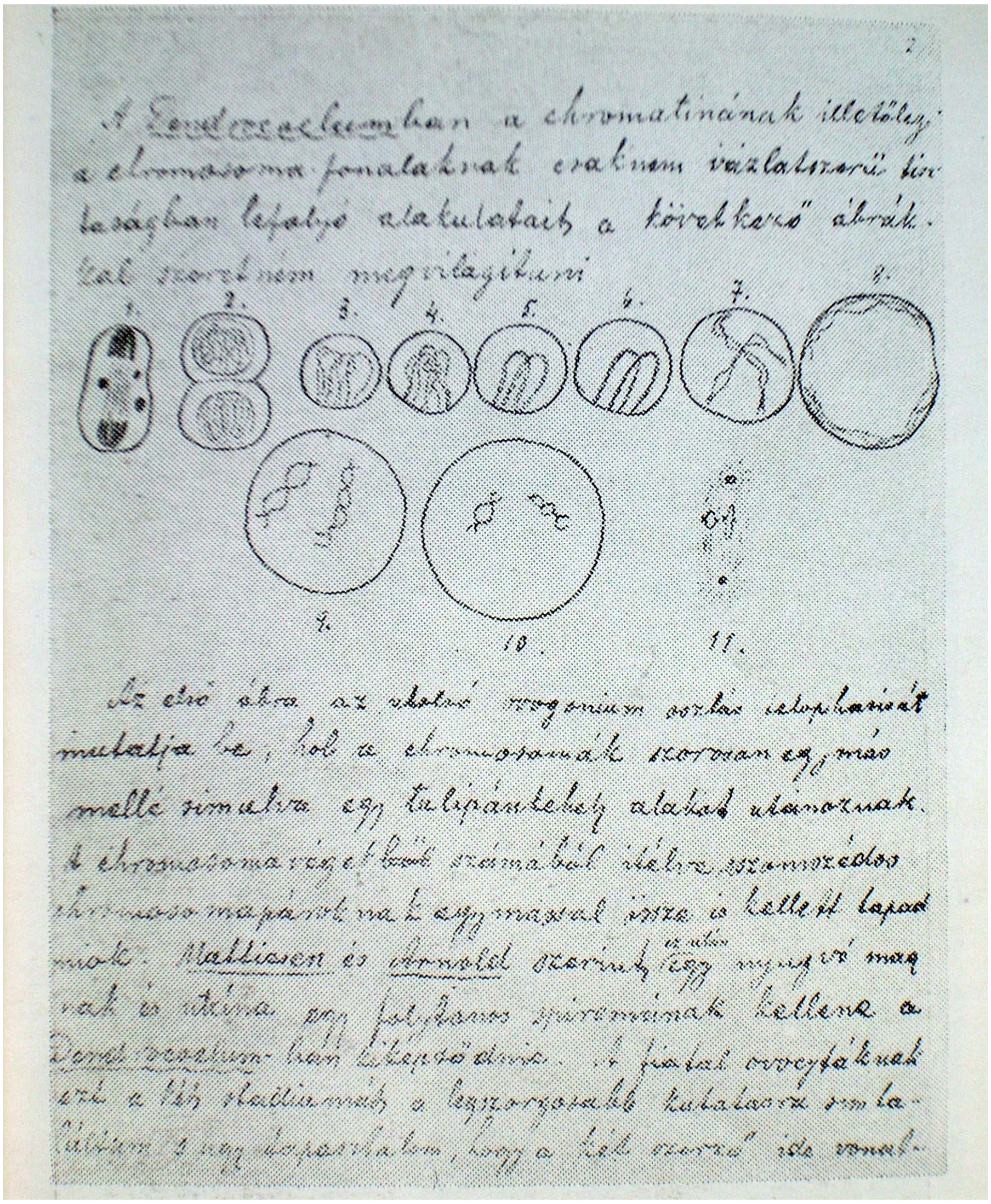
1. *Letter dated 3rd March 1913 (Gelei to Apáthy)*. Topics: arrival in Würzburg on 24th April, problems with the health of Gelei's wife, costs of living as compared to Munich and Würzburg, the very kind and friendly reception by Boveri; Boveri's exigency in selecting his staff "[Boveri] *better keeps his working places empty, than engaging improper people*", Gelei agrees that the doctors degree became inflated and is no more a guarantee for sound results in science, Boveri's satisfaction with Gelei's cytogenetic demonstrations especially regarding the longitudinal pairing of the chromosomes never seen before by him in microscopic slides, Boveri's scepticism regarding the chromidia and giant nucleoli, a Zeiss microscope with a support suited for exact localisation of the cells of special interest received by Gelei directly from Boveri, the scientific quality of the laboratories in Würzburg by Boveri as compared with that of the laboratories and people in Münich, the methods applied by Baltzer, Ubich and Schultze.
2. *Letter dated 18th March 1913 (Gelei to Apáthy)*. Topics: problems of Gelei in Würzburg due to the birth of his first child and the refusal of his academic grant asked for previously in Hungary, acknowledgement

of the advice of Apáthy regarding a personal visit to Budapest in this matter, Gelei's anticipated scepticism regarding the grant motivated by the conflict between the high ranking decision makers from the Hungarian capital and a poor fellow from the countryside; report regarding his fascinating new research interest – the effect of radium radiation on oogenesis worth of a much larger series of experiments, Boveri's generosity putting on Gelei's disposal for this experiments 17 g radium bromide received directly from Röntgen, the value of this material (3200 Mark!), Boveri's demonstrations regarding the fragmentation of irradiated [somatic!] chromosomes as well as the inability of this irradiated chromtin to self organize, differences regarding the effects of radiation on chromosomes and the cytoplasm, the value of different methods in studying the functions of the chromatin, the studies carried out by Hertwig and his co-workers in Munich in the same topics, the new goal: studies on the effects of radiation on oogenesis and on mitochondria, the advantages of *Dendrocoelum* as a model system in this field – the clear-cut chromosomal behavior during meiosis much suited for correct interpretations as compared with other model systems, birth of the idea to use this organism as a model system during a Gelei's demonstration on *Dendrocoelum* slides for Boveri, relative resistance of chromosomes against radiation in diplotene stage, disintegration of chromosomal individuality after irradiation, effect of radiation on longitudinal pairing of the chromosomes in meiosis and new research ideas and projects connected with this topic, Gelei's satisfaction for this possibility and for the confidence of Boveri toward his person and work.

3. *Letter dated 25th March 1913 (Apáthy to Gelei, draft)*. Topics: family matters connected with the Geleis' newborn baby, extra money (1000 HuK) sent by Apáthy … *für alle Fälle,* a promise for a trip to Naples, best wishes for the new research direction [called now: radio-genetics], advertising Gelei for a proper habit regarding the general scientific superficialities in observation and methodology.
4. *Letter dated 24th October 1913* (Gelei's last report from Würzburg, to Apáthy). Topics: apologies for the more sporadic research reports sent to Kolozsvár; work with the microscopic drawings, Boveri insists for finalization of the Gelei's paper in his laboratory, Boveri's satisfaction with Gelei's results: 1. Gelei's evidences regarding the random distribution of chromosomes in prophase nuclei, 2. The possible mechanisms which drive the end of the homologues together at the beginning of meiosis, 3. The observation and possible explanation of the asynchronous pairing of the different homologues, 4. The interlocking of a diplotene (paired) chromosome (or a chromatida) among the arms of a pairing one, 5. A more interesting situation when a paired chromosome end blocks the further pairing of another pair of

end blocks the further pairing of another pair of homologues, 6. The value of this evidence in arguing against those denying the existence and/or the genetic importance of the longitudinal pairing, 7. New techniques and methods developed for these studies.

All of these results – and many further ones – are presented in the printed publications of Gelei, except – quite unfortunately – a single but important topic: that of micronucleation after the irradiation of meiotic gametes (see the reproduction from a page of a letter sent by Gelei on 10th December 1912in Szabó (1976), and discussed by Imreh and Radulescu 1978, and Szabó et al. (1981).


2

A Dendrocoelumban a chromatinának illetőleg a chromosoma fonalaknak csaknem vázlatszerű térbeliségben lefolyó alakulatait a következő ábrákkal szeretném megvilágítani

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11.

Az első ábra az utolsó oogonium osztás telophasisát mutatja be, hol a chromosomák szorosan egymás mellé simulva egy tulipánkehely alakot utánoznak. A chromosoma[illegible] számából ítélve [illegible] chromosomapárok vannak egymással össze is kellett lapadniok. Mathiesen és Arnold szerint az ilyen egy nyugvó magvak is utána egy folytonos spiremának kellene a Dendrocoelum-ban kiképződnie. A fiatal oocytáknak ezt a két stádiumát a legszorgosabb kutatással sem találtam s úgy tapasztaltam, hogy a két szerző ide vonat-

Fig. 2: Micronucleation during meiosis of *Dendrocoelum* oocytes irradiated with radium bromide.
Drawings of Gelei József in a letter dated 10th December 1912.

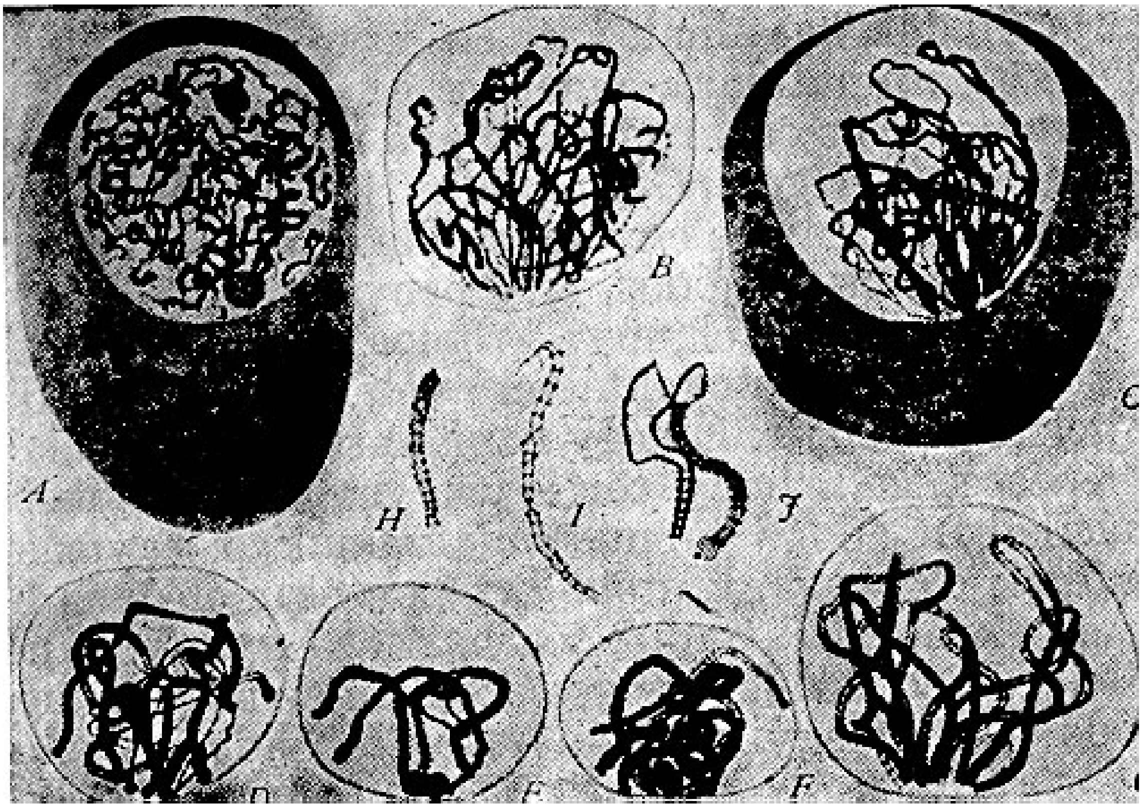


Fig. 3: Aspects of the meiosis in *Dendrocoelum lacteum* oocytes (Gelei's microscopic drawings)

A = spirema stage in the young mother cells (cca. 1500 X);
B = eptotene chromosome „bouquets” with chromatida ends grouped at a well defined area of the nuclear membrane (1500 X);
C = a leptotene bouquets with three pairing chromosomes (1500 X);
D = eptotene with five pairs (1500 X);
E-F = irregular pairing with chromosome interlocking (1100 X);
G = leptotene with two chromatids (1500 X);
H = a chromosome pair with crossing-over;
I = a chromosome pair with crossing over;
J = pairing chromosomes during the formation of structures named later “synaptonemal complex”. The individual pattern of every pair and some crossing over are clearly represented here.

Gelei (1920) in Sharp cf. Szabó Z (1938) Online source: Takács and Szabó (2001): http://genetics.bdf.hu/Htmls/Studwork/tviktoria/index.htm

Why was Gelei neglected in Genetics?

The fate of the life work of Gelei in genetics was strongly influenced by non-scientific factors: the disintegration of the Austro-Hungarian Empire in 1920; the German defeat and consequently the slow language shift in science from German to English between the two World Wars; the effects of the once dominant ideology of the period – the Lysenkoism (see Dubinin

1975 for details). The rediscovery of Gelei's works is still in advance, but paradoxically this process is especially slow in his home countries Hungary and Romania. This fact deserves a special scientific investigation.

All of these facts contributed to the relative ignorance of Gelei in genetics, but did not explain it fully. Some main points are presented here, because in different historical periods of Gelei's scientific life, many different factors contributed to the neglect:

1. Gelei started his scientific life as a protistoligist and taxonomist, belonging to no "genetic" school;
2. The Zoological Institute of the University of Kolozsvár was famous not for its genetic, but for its histological and neurobiological achievements, such as for the continuity *versus* contiguity debate between A-páthy and Ramon y Cajal on the structure and function of the nervous system;
3. Gelei left Germany quickly after his genetic results were achieved and even Boveri died in 1922, exactly at the time when Gelei published his monograph on the longitudinal pairing of meiotic chromosomes and the significance of this process in heredity in German and Hungarian languages;
4. The results were published exactly after the defeat of Germany and his allies, the collapse of the Austro-Hungarian Empire and consequently in a period of adversity against publications written in these languages, published in these countries;
5. In 1920 Gelei was forced to leave his homeland Transylvania, move to Hungary and integrate in his – severely humiliated – new homeland,
6. Gelei was in a very competitive situation, especially with the professors coming here from Transylvaia such as with Győrffy István, the father of Győrffy Barna and both interested in genetics;
7. The contemporary Hungarian science was not really prepared for the reception of genetic high science of the time. For example S. Zoltán (1938), the best and really well documented Hungarian phytogeneticist – a contemporary of Gelei and author the first comprehensive high level Hungarian handbook on genetics – mentions just in passing the results of Gelei (citing not him, but an English manual citing Gelei), without any sign of comprehension of the due significance of his results (Fig. 3., cf. also Győrffy 1964/1965).
8. After leaving Transylvania in 1920 Gelei focused almost exclusively on protistolgy and was deeply involved in management of science and teaching as a founding member of a "new" university (the University of Kolozsvár moved to Szeged);

9. His second Transylvanian period, between 1940-1945, was an almost completely new beginning, which ended with a new catastrophe;
10. For the genetic heritage of Gelei the most destructive period was that of Lysenkoism (mostly between 1945-1952, but with lasting effects also later) which destroyed most of his books and reprints in genetics available in institutional and public libraries, even in the central library of the Hungarian Academy of Sciences.
11. Gelei's books and papers on chromosomes were never translated in full length into English.

The topics discussed here may have some significance for all who study science history, the nature of paradigm shifts in genetics, but also for those interested in human scientific behavior in particular historical times and/or in particular geographic zones. This is especially true for studies related to the evolution of the Weismannian germplasm concept in America and the Soviet Russia and the emergence of the conservation science and the protection of the agro/ethno/biodiversity (Hammer 1998, 2001, 2003, 2003a, 2008).

Science and Religion

During the International Darwin Year 2009 it is perhaps of interest to mention the common Unitarian backgrounds of both the Darwin-Wedgwood families and that of the Gelei family. The Unitarian world view has deep roots both in the Hebrew world view and in scientific thinking. The founder of the religion, Michael Servetus was a medical doctor and many influential early Unitarians in Transylvania were also scientists. The new religious affiliation of Gelei emerged in his home land Transylvania, especially among the Unitarian religious communities and led to a strange interference between science and religion, quite neglected in history of science and even in scientometry (de Candolle 1885, Szabó 1985).

Acknowledgements

The author would like to acknowledge the help of Gábor Dénes (Kolozsvár) in saving and putting on his disposal the Gelei correspondence, of Dr. Kiss Keve Tihamér (Danube Research Station of Hungarian Academy of Science DRS – HAS in Alsógöd) for helping to unravel the scientific heritage of his grandfather Gelei József, of Dr. Imreh István (Karonliska Institute, Stockholm) and Dr. Vörös Lajos (Balaton Limnological Research Station – BLRI-HAS in Tihany) and of Dr. Balogh Lajos (Savaria Museum, Szombathely).

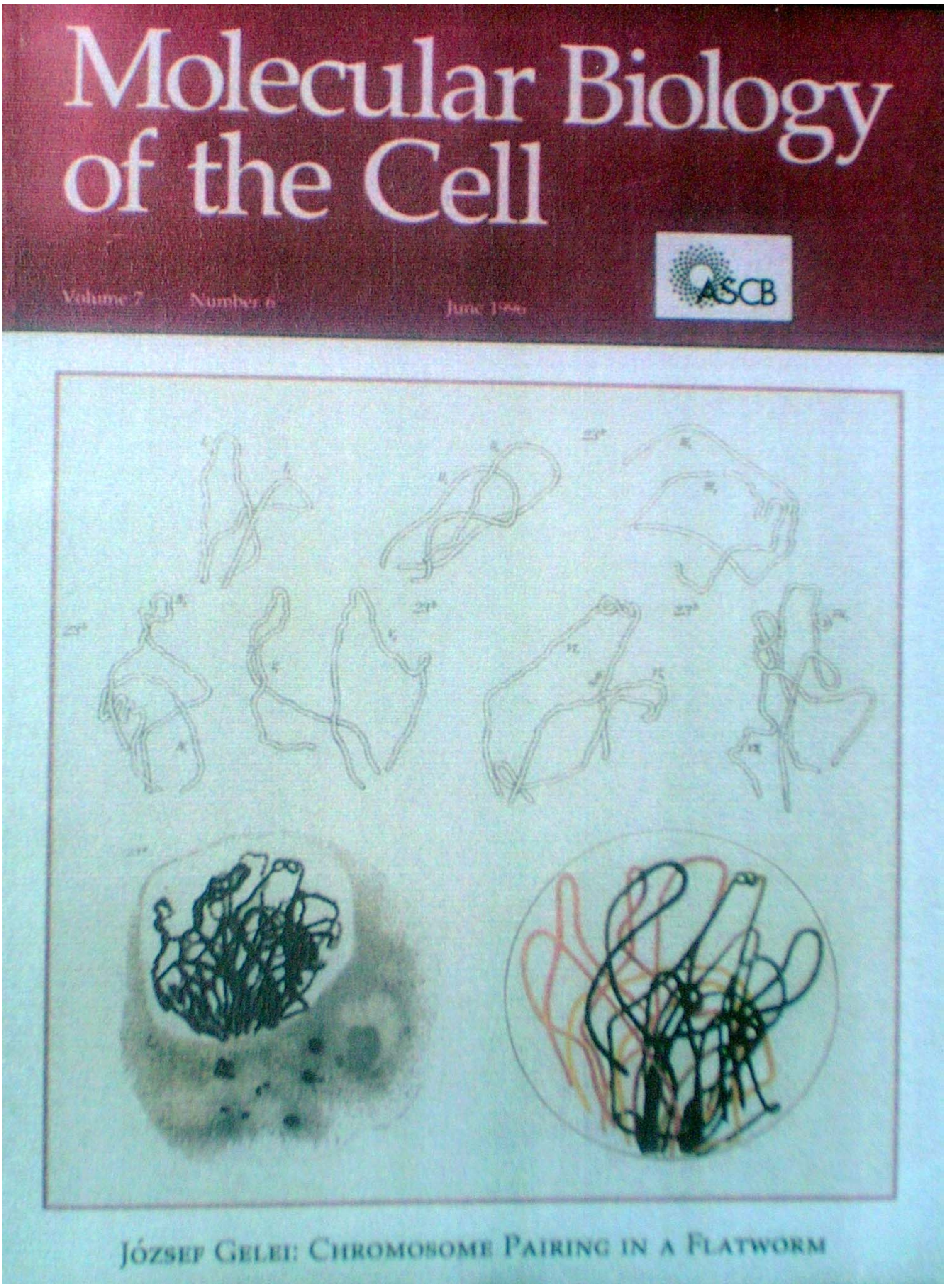


Fig. 4: Title page of the journal "Molecular Biology of the Cell" vol. 7. nr. 6, 1996 original drawings of Gelei József regarding "Chromosome Pairing in a Faltworm – *Dendrocoelum lacteum*"

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* * * 1889 First PI number in the USA Seed and Plant Introduction Section

ESFAHANIAN EMMER (*TRITICUM ISPAHANICUM* HESLOT) – A CASE OF AN EXTINCT ON-FARM CROP

Korous Khoshbakht

Abstract

Triticum ispahanicum Heslot, described in 1958, has been considered a rare endemic of Iran (mountains area near Esfahan city). Recent efforts to find this species in Iran have not been successful. Therefore, it is proposed under the IUCN category of " Extinct in the wild" (extinct *On-farm* crop). History, use, origin and evolution of *T. ispahanicum* are briefly considered in the light of new expeditions.

Key words:
Iran, extinct crop, wheat

Introduction

In Iran*Triticum ispahanicum* was discovered in 1957 by the French expedition of Vinnot-Bourgen in a few villages of the Vazak Canton. Heslot (1958) described this rare tetraploid species from almost pure sowings of irrigated fields in the region of Faridan, Esfahan Province (W Iran) at an altitude of 2000 to 2500 m.

T. ispahanicum (Fig. 1) is similar to *T. dicoccon* Schrank in vegetative organs, the type of spike disarticulation and the difficult threshability (Dorofeev et al. 1979, Miller 1987). Therefore, the following combination was published: *T. dicoccon* ssp. *ispahanicum* (Heslot) Dorofeev in Vestn. Selsko-choz. Nauk: 3 (1965) 27. But, there are also similarities with *T. polonicum* L., especially in the elongated lemmas and glumes, elongated caryopsis and one-sided orientation of the spikelets (Mac Key 1963, Migušova and Žukovskij 1969, Dorofeev et al. 1979). As a consequence, most researchers such as Kihara et al. (1965) and Kuckuck (1956) included *T. ispahanicum* into *T. polonicum*. Hanelt (2001) stated that the taxonomic position and rank of it remained still open. Other wheats with long glumes are *T. polonicum*, *T. durum* Desf. convar. *falcatum* (Jakubz.)Dorof. et A. Filat. (tetraploid) and *T. petropavlovskii* Udač. et Migusch. (hexaploid) (Watanabe and Imamura 2002).

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Fig.1: *Triticum ispahanicum* Heslot (photo from a herbarium specimen).

Materials and Methods

A special survey carried out in the former area of *T. ispahanicum* distribution in 2005 and repeated again in 2007 and 2008. None of these expeditions yielded positive results (Table 1; Fig. 2, 3). In the.”Flora Iranica” *T. ispahanicum* species is also absent (Bor 1970). So it was concluded that *T. ispahanicum* reached the status of an extinct crop plant (Hammer and Khoshbakht 2005) in agriculture. A few accessions are still available in genebanks and other collections as evidenced by scientific papers including *T. ispahanicum* in their studies (e.g. Brežnev 1979, Szabó and Hammer 1996, Watanabe et al. 2002, Wang et al. 2002).

Table 1. The geographical characteristic collection of sites in Iran

Sites	Longitude (N) ..º ..′	Latitude (E) ..º ..′	Altitude (m.asl.)
Bazmeh 1	32 52	50 17	2308
Bazmeh 2	33 01	50 09	2393
Khoygan	33 00	50 10	2380
Khoygan olya	33 00	50 10	2425
Choghador 1	32 51	50 18	2319
Choghador 2	32 53	50 13	2367
Cheghyort	32 58	50 01	2681
Sorosh jan	32 54	50 11	2399
Bade jan	32 55	50 10	2392
Gohar dareh 1	32 58	50 11	2358
Gohar dareh 2	32 25	49 52	2395
Eslam abad 1	32 58	50 11	2358
Eslam abad 2	33 00	49 50	2490
Vahdat abad	32 55	50 10	2407

Results and Discussion

T. ispahanicum was always rare. Apart from the Heslot-material, Kihara et al. (1956) described a race, which seems to be identical to *T. ispahanicum* (Watanabe 1999). The material of Kihara et al. (1959) came from the Herbarium of Tehran, collected by Dr. M. Atai and preliminary determined as *T. monoccum* L. var. *eredvianum* Zhuk. Here we have an early report about our species (see also Kihara et al. 1965). Still earlier is material of Kuckuck (FAO collecting mission 1952-1954). This material was conserved in the Herbarium Gatersleben* (coll.nr. 444a, Sengbaran, 2380 m NN, Iran=TRI 6177) and was determined as *T. ispahanicum*. After Heslot (1958) there were no reports about successful finding of *T. ispahanicum*, (Damania et al. 1993).

T. ispahanicum is reported as an ancient wheat in Iran (Heslot 1958). It was used in the same way as *T. dicoccon*. The same is true for Oman where the species is known as ”Alas” (*T. dicoccon*) and has the same folk name. As

* Many thanks to Dr. K. Pistrick, curator of the Gatersleben Herbarium (GAT).

the cultivation is declining or has already declined, the use of *T. ispahanicum* is mainly a genetic resource. Esfahanian emmer is severely damaged by powdery mildew, stem rust and stripe rust, but it shows immunity to loose smut and covered smut. A high susceptibility was observed for brown rust at the seedling stage, whereas adult plants showed some resistance (Dorofeev et al. 1979). Grain quality and elongated glumes may be other desirable characters (Wang et al. 2002).

Fig.2: Map of Iran showing the Esfahan Province in the central west of Iran.

Many characteristics of *T. ispahanicum* indicated that it might be a cross between *T. dicoccon* and *T. polonicum* (Kuckuck and Schieman 1957, Gandilyan 1974, Hanelt 2001). On the other hand, *T. ispahanicum* could have evolved from a spontaneous mutation of glume length (Chelak 1978). Recently, Watanabe (1999) showed that *T. ispahanicum* originated most likely as a mutation of a gene affecting glume length on chromosome 7 B of *T. dicoccon*. The origin of *T. ispahanicum* by mutation from *T. dicoccon* is also supported by electrophoretic spectra of protein (Dorofeev et al. 1979).

Newly reported material from Oman offers interesting new aspects (Alkhanjari et al. 2005, Alkhanjari 2005). Hypothetically is the introduction of Esfahanian emmer together with *T. dicoccon* from Iran which is closely related to Iranian emmer (and not to the Ethiopian one). As the first remains of wheat in Oman date back to approximately between 5000 and 3500 B.C. (Willcox and Tengberg 1995), there is a probability that *T. ispahanicum* arrived also very early and possibly existed side by side with *T. dicoccon*. But also an emergence from *T. dicoccon* cannot be excluded.

Here we find another example to support the hypothesis that Oman and Iran are both centres of confluence of plant genetic resources and for the conservation of plant genetic resources. In connection with the Arabian world, Ethiopia and especially Iran led to an interesting flora of cultivated plants. Undoubtedly wheat landraces in the region need further exploration to better understand their use, origin, genetic diversity and potential for future breeding programs.

Fig.3: Researchers looking for *T. ispahanicum* in local farms (Faridan, Esfahan Province (W Iran), July 2008.

Acknowledgements

This research was supported by a grant of the Shahid Beheshti University. The author expresses his gratitude to the vice-presidency for research and technology for its financial support.

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