Nucleic Acids Research, 2016 1 doi: 10.1093/nar/gkw755

# EURISCO: The European search catalogue for plant genetic resources

Stephan Weise<sup>1,\*</sup>, Markus Oppermann<sup>1</sup>, Lorenzo Maggioni<sup>2</sup>, Theo van Hintum<sup>3</sup> and Helmut Knüpffer<sup>1</sup>

<sup>1</sup>Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) Gatersleben, Corrensstr. 3, 06466 Stadt Seeland, Germany, <sup>2</sup>Bioversity International, Via dei Tre Denari 472/a, 00057 Maccarese (Fiumicino), Rome, Italy and <sup>3</sup>Centre for Genetic Resources, The Netherlands (CGN), Wageningen University and Research Centre, P.O. Box 16, 6700 AA Wageningen, The Netherlands

Received July 28, 2016; Revised August 19, 2016; Accepted August 21, 2016

### ABSTRACT

The European Search Catalogue for Plant Genetic Resources, EURISCO, provides information about 1.8 million crop plant accessions preserved by almost 400 institutes in Europe and beyond. EURISCO is being maintained on behalf of the European Cooperative Programme for Plant Genetic Resources. It is based on a network of National Inventories of 43 member countries and represents an important effort for the preservation of world's agrobiological diversity by providing information about the large genetic diversity kept by the collaborating collections. Moreover, EURISCO also assists its member countries in fulfilling legal obligations and commitments, e.g. with respect to the International Treaty on Plant Genetic Resources, the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture of the United Nation's Food and Agriculture Organization, or the Convention on Biological Diversity. EURISCO is accessible at http://eurisco.ecpgr.org.

### INTRODUCTION

Crop plants are a major source for human and animal nutrition (1). Moreover, they play an important role for chemical and pharmaceutical industry and as renewable resources (2,3). To assure the future availability of the genetic diversity of crop plants and their wild relatives for use in plant breeding and research, this diversity needs to be preserved. Genebanks play an important role in the long-term conservation efforts of plant genetic resources for food and agriculture (PGRFA). However, their focus is not on conservation only. Genebanks also collect data about the material they conserve, thus allowing users to select the most appropriate material for use in their breeding or research programmes (4). An important component thereof is phenotypic characterisation of genebank accessions, i.e. collecting information about traits such as disease resistance, drought tolerance and yield components. These data are usually generated on selected material, resulting in non-orthogonal, highly incomplete data sets. Nevertheless, the analysis of these data allows meaningful results, e.g. the identification of promising new alleles (5). Around the world, there are about 1800 genebank collections conserving PGRFA. Thereof, about 625 collections are maintained in Europe comprising more than 2 million accessions (6).

The European Search Catalogue for Plant Genetic Resources (EURISCO) provides information about 1.8 million crop plant accessions comprising 6233 genera and 41 649 species. EURISCO was initially developed between 2001 and 2003 within the EU-funded project EPGRIS (European Plant Genetic Resources Information Infra-Structure) coordinated by the Centre for Genetic Resources, The Netherlands (CGN), and with the participation of the Czech Republic, France, Germany, Portugal, the International Plant Genetic Resources Institute (IPGRI, now Bioversity International) and the Nordic Gene Bank (NGB, now NordGen). In 2003, EURISCO became online accessible (7) and was hosted by Bioversity International, Rome, Italy, on behalf of the European Cooperative Programme for Plant Genetic Resources (ECPGR). In 2014, the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben, Germany, took over responsibility for the operation and development of EURISCO, as well as for the coordination of the EURISCO Network, still on behalf of ECPGR. The system was re-engineered completely and transferred to a new technological basis.

EURISCO is based on a network of National Focal Points (NFPs), who develop and maintain National Inventories (NIs) of the PGRFA holdings conserved in *ex situ* collections within their respective countries. The maintenance of most of these collections is supported by various management systems allowing provision of data to the respective NFPs who standardise the data in their NI, and regularly

© The Author(s) 2016. Published by Oxford University Press on behalf of Nucleic Acids Research.

<sup>\*</sup>To whom correspondence should be addressed. Tel: +49 39482 5 744; Fax: +49 39482 5 155; Email: weise@ipk-gatersleben.de

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

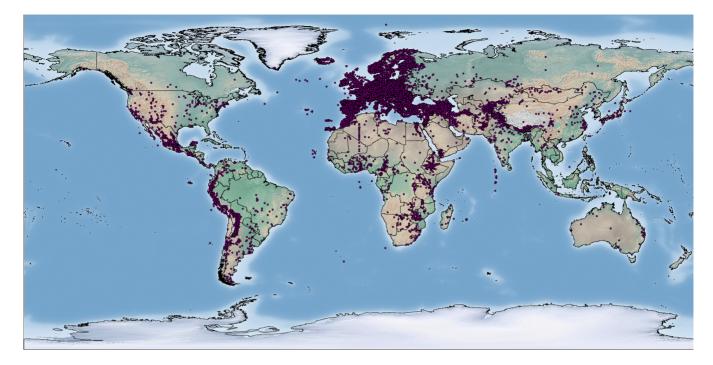


Figure 1. Collecting sites of accessions with geographical coordinates listed in EURISCO (map created by DIVA-GIS v7.5.0.0).

upload it to EURISCO, thus creating a complete overview of PGRFA in Europe.

# DATABASE DESCRIPTION

### Content

EURISCO contains both passport data and phenotypic information about plant genetic resources maintained in *ex situ* collections in Europe. Besides a research collection of the Nottingham Arabidopsis Stock Centre (http: //arabidopsis.info/) comprising almost 670 000 *Arabidopsis thaliana* accessions, the major crops contained in EU-RISCO are wheat, barley and maize, respectively, which are among the top five major cereal grains produced worldwide (8). Table 1 gives an overview of the composition of EU-RISCO by plant species. The largest contributing National Inventories are those of the United Kingdom, Germany and the Russian Federation (Table 2).

The participating PGRFA collections, due to their geographical location, focus on materials that can be maintained in the temperate climate zone. Twenty-eight countries of origin are represented by more than 10 000 accessions each, and 16 countries by more than 20 000 accessions, the five most frequent being Spain (66 327), Germany (55 349), the Russian Federation (49 781), USA (47 754) and Ukraine (43 617). The collecting sites of 188 454 EURISCO accessions having geographical coordinates are illustrated in Figure 1.

Additionally, EURISCO enables National Focal Points to label PGRFA accessions as part of AEGIS (A European Genebank Integrated System (6), http://aegis.cgiar. org/). AEGIS is an ECPGR initiative, aiming at improving the coordination of the conservation and management of PGRFA as well as the access to them, to ensure a safe longterm conservation (with common agreed standards) of genetically unique and important accessions. In order to reduce redundancy, the responsibilities for conservation are clearly defined. AEGIS is not a physical collection, but a virtual genebank. Changes of its composition are audited in EURISCO.

### Web interface

The central entry point to EURISCO is the web interface (http://eurisco.ecpgr.org), shown in Figure 2.

The user interface provides different possibilities of retrieving information. Four standard searches are available, which enable the users to quickly search only those fields that are related to taxonomy, accession, biological status and collecting site, respectively. Additionally, an advanced search was implemented that allows to combine all available fields within a single search. Moreover, the available phenotypic data can also be searched and user-specific filter rules can be defined on the generated reports (Figure 3). All reports are available for download. In addition, various user-specific export functionalities including a full dump in MS-Access format are provided.

Furthermore, a variety of statistical reports as well as documents describing the background and the architecture of the EURISCO network are given. For disseminating information about EURISCO, a newsletter system using double opt-in was implemented.

For the development of the web interface, the Oracle Application Express (APEX, https://apex.oracle.com/) technology, version 5, was used. Further means of access, such as web service APIs, will be provided in the future.

			Home	About	Search	C&E data	Statistics and documents	s Imprint / Data Protection P
me News								
								Search EURISCO
come to EURISCO								> Quick search
pean network of exples. Neen 2003 and 2014,	alogue providing information about ex situ pla situ National Inventories (NIs). Currently, EL EURISCO was hosted and maintained by B	JRISCO comprises passpo	me, Italy. Since	1.8 million e 15th April	coordina	aits gene ited con einforma	GIStoceand tic genebank imunity % ationegr of Maria	<ul> <li>&gt; Advanced search</li> <li>&gt; Export EURISCO data</li> <li>&gt; C&amp;E data</li> </ul>
rsleben, Germany. A	es are being moved to the Leibniz Institute when adapting to a new IT infrastructure, imp activities and incorporating phenotypic inform	portant medium-term actio	ons and objection	ves will be	4 Poo	EURI		EURISCO newsletter
	on behalf of the Secretariat of the European C				pecies instituti	acces	sions	Subscribe / unsubscribe
PGR), in collaboration	with and on behalf of the National Focal Poin	ts for the National Inventor	ries.		Institut	α <sub>ί</sub> ς ECP		Regions of origin
s 16-06-13: National Inv	rentory data of The Netherlands updated					CMYHDS		N M
16-06-10: National Inv	ventory data of Latvia updated - new AEGIS ad	ccessions						Statistical overview
16-06-02: National Inv	rentory data of Poland updated - new AEGIS a	iccessions						1,842,300 Accessions 376 Institutes 43 Countries 6,233 Genera 41,644 Species
GBR (United Kingdom)	800,358	Arabidopsis Triticum		,055		6	69,587	368,240 MLS access
DEU (Germany) US (Russian Federation)	123,430	Hordeum	105,289					28,847 AEGIS
UKR (Ukraine)	94,025	Zea	61,932					accessions
ESP (Spain)	76,984	Phaseolus	49,774					Site rating
POL (Poland)	69,757	Solanum .	32,740					
BGR (Bulgaria)	63,713	Pisum	29,735					Your rating:
CZE (Czech Republic) HUN (Hungary)	52,947 46,750	Avena Vitis	29,429					0*****
ROU (Romania)	46,750	vius Malus	28,819					Submit
other	293,935	other				64	i0,242	Average:
							000	****
	0 200,000 400,000 600,000 800,000 1,000,000		0 100,000	300,000	500,0			

Figure 2. Overview screenshot of the EURISCO web interface.

### **Database implementation**

EURISCO was implemented on the basis of the Oracle relational database management system, version 12c (https: //www.oracle.com/database/). The system comprises two parts, a so-called staging area for pre-processing and cleansing of data as well as database structures for the web frontend. The underlying database schema consists of 45 tables for the staging area, 40 tables for the front-end, 26 materialised views and 15 PL/SQL packages comprising 133 functions serving mainly for data quality assurance, user-specific download functionalities and reporting tasks.

# UPDATE PROCESS, QUALITY ASSURANCE AND CONTINUATION

The germplasm accessions listed in EURISCO are maintained by almost 400 institutes within the member countries. These institutes provide the data to their National Focal Points who compile the National Inventories of their respective countries and upload them to EURISCO, preferably at least once per year. For data exchange, standardised formats are used (FAO/Bioversity Multi-Crop Passport Descriptors format for passport data and a EURISCOspecific format for phenotypic data).

Via an intranet, data are uploaded by the National Focal Points into the staging area where they are extensively cleansed and checked for consistency. In this context, the correctness of scientific plant names (9) and the accuracy of geographic coordinates of collecting sites pose important challenges. The existing procedures allow the detection of typos in the taxonomy, while the geographical coordinates are automatically checked for compliance with the defined format, e.g. correct ranges of degrees, minutes, etc. There is

Table 1.	Content of the EURISCO	database grouped b	by taxonomy showing	g the ten most frequent genera

Genus	Species	No. accs.	Total
Arabidopsis	<i>thaliana<sup>a</sup></i>	669 381	669 587
x	others	206	
Triticum	aestivum	104 985	147 055
(wheat)	durum	10 071	
	turgidum	8647	
	monococcum	3312	
	spelta	2760	
	others	17 280	
Hordeum	vulgare	84 087	105 289
(barley)	spontaneum	9746	
	others	11 456	
Zea	mays	61 799	61 932
(maize)	others	133	
Phaseolus	vulgaris	44 031	49 774
(garden bean)	coccineus	2829	
	others	2914	
Solanum	lycopersicum	18 338	44 400
(tomato, potato, eggplant, etc.)	tuberosum	13 857	
	melongena	2540	
	others	9665	
Pisum	sativum	26 517	29 735
(pea)	others	3218	
Avena	sativa	22 690	29 429
(oat)	sterilis	2123	
	byzantina	1045	
	others	3571	
Vitis	vinifera	24 941	28 819
(grape)	others	3878	
Malus	domestica	23 979	27 698
(apple)	others	3719	
others			649 034
		Total	1 842 752

<sup>a</sup>Model plant in life sciences research.

 Table 2.
 The ten largest National Inventories providing data to EURISCO

Country	No. accs.	Percentage
United Kingdom	800 358	43.43%
Germany	174 362	9.46%
Russian Federation	123 430	6.70%
Ukraine	94 025	5.10%
Spain	76 984	4.18%
Poland	70 209	3.81%
Bulgaria	63 713	3.46%
Czech Republic	52 947	2.87%
Hungary	46 750	2.54%
Romania	46 039	2.50%
others	293 935	15.95%
Total	1 842 752	100.00%

room for additional developments in order to further improve the support to the data providers.

After approval by the data providers, the data are synchronised with the EURISCO web front-end (Figure 4).

Both data content and IT infrastructure are being improved continuously. The long-term maintenance of the EURISCO network will be ensured in the frame of the European Cooperative Programme for Plant Genetic Resources.

### APPLICATION

EURISCO serves a wide variety of applications in both preservation of biological diversity and crop plant research.

The central mission of EURISCO is to provide a onestop-shop for information about the large genetic diversity existing in the collaborating collections for the scientific community and for plant breeders. In order to achieve the aim of sustainable breeding it is indispensable to mine the wealth of largely untapped genetic resources, such as crop wild relatives and old landraces. Here, EURISCO can provide important impulses since it maintains, amongst others, information about 233 905 crop wild relative accessions as well as about 252 130 landrace accessions.

Moreover, EURISCO also supports the coordination of efforts of the long-term maintenance of plant genetic resources among genebanks. It helps the member countries in fulfilling legal obligations and commitments, e.g. with regard to the International Treaty on Plant Genetic Resources (ITPGRFA, http://www.planttreaty.org/), the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Second GPA, http://www.fao.org/ agriculture/crops/core-themes/theme/seeds-pgr/gpa/en/) of the United Nations Food and Agriculture Organization (FAO), or the Convention on Biological Diversity (CBD, https://www.cbd.int/), to name a few. All these agreements require the Parties to provide a transparent documentation of their respective PGRFA.

	species and tr	aits Filter by g	Eilte	r by expe	rimont E	ilter by trait		Home About Search			
		by species and trait.>									
e, / Gae	uata, 2 Geardin	by species and trait.	Traits for experim	nenvspeci	es / Trait detai	15					
ait details	s									< Back	Search EURISCO
istributio	on of scores			D	escriptive stat	istics					> Advanced search
					Trait Name	Minimum Maximum Av	verage Stddev Variance	First Quartile Median Thire	d Quartile		> Export EURISCO data
	2-13			1	Head shape	1 4 1.	76 .87 .75	1 2 2			>C&E data
			3-3		Experiment description			ence varieties. Field trial. sowin oject. IVT grounds. Wageningen		3. planting date	
					Trait name	Head shape					
					Trait method	At harvest maturity, in le	ongitudinal section(0=no head	, 1=elliptic, 2=broad el., 3=circu	ılar, 4=transv	verse el.)R	
		1-15			Limited to species	Lactuca dregeana DC.; Lactuca quercina L.; La	Lactuca georgica L.; Lactuca ictuca raddeana Maxim; Lactu tuca tatarica (L.) C. A. Mey.; L	; Lactuca biennis (Moench) Fer homblei De Wild.; Lactuca indic ca saligna L.; Lactuca sativa L.; actuca tenerrima POURR.; Lac	ca L.; Lactuc ; Lactuca sat	a perennis L.; iva x serriola ;	
					Additional						
					Species	Lactuca sativa I					
						Lactuca sativa L.	of selected trait - V				
cession	scores for sel	lected trait			Species	Lactuce setive L.					
cession : Q ~	scores for se	lected trait	Go		Species Drigin Country						
Q~	]		Go	(	Species Drigin Country	All origin countries o					
	]	ected trait	Go	(	Species Drigin Country	All origin countries o					
Q~ • •			Go	(	Species Drigin Country	All origin countries o					
Q ~ ▼ _ 1 - 10 of	∑ <mark>∑ Sco</mark> f 18 )		Go	(	Species Drigin Country	All origin countries o	of selected treit – V			Details	
Q ✓ ▼	∑ <mark>∑ Sco</mark> f 18 )	re >= 2	ACCENUMB	Rows	Species Drigin Country	All origin countries of	of selected trait - V	ogical Status var (conventional breeding meth	hods) Acc	Details ession details	
Q ✓ ▼	Soc f18 Soc INSTCODE	re >= 2 Species	ACCENUMB	Rows Score 2	Species Drigin Country	All origin countries of ctions >>	of selected trait – V Biol Advanced or improved culti				
Q ✓ ▼	F18 Soc INSTCODE NLD037 NLD037 NLD037	rre >= 2 Species Lactuca sativa L Lactuca sativa L Lactuca sativa L	ACCENUMB CGN05206 CGN04696 CGN05204	Rows Score 2 2	Species Drigin Country	All origin countries of ctions  Origin Country France United States Russian Federation	of selected trait – V Biol Advanced or improved culti	var (conventional breeding meth	hods) Acc	ession details	
Q → 1 - 10 of ICODE LD LD LD LD	Sec f18 S INSTCODE NLD037 NLD037 NLD037 NLD037	re >= 2 Species Lactuca sativa L. Lactuca sativa L. Lactuca sativa L. Lactuca sativa L.	ACCENUMB CGN05206 CGN04896 CGN05204 CGN05213	Rows Score 2 2 2 2 2 2	Species Drigin Country	Origin Country     France United States Russian Federation Islamic Republic of Iran	ef selected trait – V ef selected trait – V Biol Advanced or improved culti Advanced or improved culti Traditional cultivar/landrace Advanced or improved culti	var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth	hods) Acc Acc hods) Acc	ession details ession details ession details ession details	
Q ✓ 1 - 10 of ICODE ID ID ID ID ID ID ID	Sco Sco Sco IN STCODE NLD037 NLD037 NLD037 NLD037     NLD037	re >= 2 Species Lactuca sativa L Lactuca sativa L Lactuca sativa L Lactuca sativa L Lactuca sativa L	ACCENUMB CGN05208 CGN04698 CGN05204 CGN05213 CGN06018	Rows Score	Species Drigin Country	All origin countries of ctions      Origin Country France United States Russian Federation Islamic Republic of Iran Netherlands	of selected trait –      Eiol     Advanced or improved culti     Traditional cultivarilandrace     Advanced or improved culti     Advanced or improved culti	var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth	hods) Acc Acc hods) Acc hods) Acc	ession details ession details ession details ession details ession details	
Q ✓ 1 - 10 of ICODE ID ID ID ID ID ID ID ID	Societ     Societ	re >= 2 Species Lactuca sativa L Lactuca sativa L Lactuca sativa L Lactuca sativa L Lactuca sativa L	ACCENUMB CGN05208 CGN04698 CGN05204 CGN05213 CGN06018 CGN04801	Rows Score	Species Drigin Country	Crigin Country     France     United States     Russian Federation     Islamic Republic of Iran     Netherlands     Turkey	f selected trait –      For      Biol     Advanced or improved culti     Advanced or improved culti     Traditional cultivar/landrace     Advanced or improved culti     Traditional cultivar/landrace	var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth	hods) Acc Acc hods) Acc hods) Acc Acc	ession details ession details ession details ession details ession details ession details	
Q → 1 - 10 of iCODE ID ID ID ID ID ID ID ID ID	Sec     S	re >= 2  Species Lactuca sativa L	ACCENUMB CGN05208 CGN05204 CGN05204 CGN05213 CGN06018 CGN06018 CGN04801 CGN05277	Rows Score 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Species Drigin Country	Crigin Country  France United States Russian Federation Islamic Republic of Iran Netherlands Turkey Israel	f selected trait –      F	var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth	hods) Acca Acca hods) Acca Acca Acca Acca Acca	ession details ession details ession details ession details ession details ession details	
Q → 1 - 10 of ICODE ID ID ID ID ID ID ID ID ID ID	Sec     S	re >= 2  Species Lactuca sativa L	ACCENUMB CGN05206 CGN04698 CGN05204 CGN05213 CGN06018 CGN06018 CGN04801 CGN05277 CGN04622	Correct Correc	Species Drigin Country	Crigin Country     Crigin Country     France     United States     Russian Federation     Islamic Republic of Iran     Netherlands     Turkey     Israel     United States	f selected trait –      F	var (conventional breeding meth var (conventional breeding meth	hods) Acce Acce hods) Acce hods) Acce Acce hods) Acce hods) Acce	ession details ession details ession details ession details ession details ession details ession details ession details	
Q → 1 - 10 of ICODE ID ID ID ID ID ID ID ID ID ID	Sec     S	re >= 2  Species Lactuca sativa L	ACCENUMB CGN05206 CGN05204 CGN05204 CGN05204 CGN05213 CGN06018 CGN04801 CGN05277 CGN04922 CGN13296	Rows         Score           2         2           2         2           2         2           2         2           2         2           4         4	Species Drigin Country	Crigin Country  France United States Russian Federation Islamic Republic of Iran Netherlands Turkey Israel	f selected trait –      F	var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth var (conventional breeding meth	hods) Acc Acc hods) Acc hods) Acc hods) Acc hods) Acc hods) Acc	ession details ession details ession details ession details ession details ession details	

Figure 3. Filtering of phenotypic data using the EURISCO web interface.

### DISCUSSION

EURISCO contains information about plant genetic resources for food and agriculture maintained in almost 400 institutions in Europe and beyond. It represents an important effort for the preservation and accessibility of world's biological diversity.

Besides the classical passport data, the system also provides phenotypic information about germplasm accessions. While the FAO/Bioversity Multi-Crop Passport Descriptors standard provides a well-established exchange format for passport data, there is no widely accepted format for phenotypic data existing (10). However, the scientific community is on the move. Initiatives such as Minimum Information about Plant Phenotyping Experiments (MIAPPE (11), http://www.miappe.org/) or CropOntology ((12), http://www.cropontology.org/) are emerging and could, in the long-run, lead to a significant improvement in the exchange and interpretation of phenotypic data.

Currently, EURISCO is limited to accessions maintained in *ex situ* collections. However, the inclusion of information about PGRFA maintained *in situ* is one of the development goals of the European Cooperative Programme for Plant Genetic Resources, which will be implemented in EU-RISCO in the future.

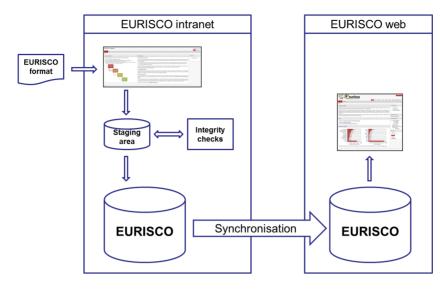


Figure 4. Architecture overview of the update process.

# CONCLUSION

EURISCO is an ongoing initiative that provides information about the majority of PGRFA accessions maintained in European collections. The vision for the system is in two directions: further extension of the database content in connection with increasing data quality, and improvement of the web interface.

Moreover, EURISCO will continue to cope with actual and upcoming topics within the PGRFA community, such as improved support for phenotypic data or unique identification of germplasm accessions.

# ACKNOWLEDGEMENTS

The authors wish to thank the network of the EURISCO National Focal Points as well as all institutions providing data for their hard work and great commitment.

# FUNDING

Development and maintenance of EURISCO: European Cooperative Programme for Plant Genetic Resources (ECPGR), Rome, Italy. Funding for open access charge: Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben, Germany.

Conflict of interest statement. None declared.

# REFERENCES

- Grusak, M.A. and DellaPenna, D. (1999) Improving the nutrient composition of plants to enhance human nutrition and health. *Annu. Rev. Plant Physiol. Plant Mol. Biol.*, 50, 133–161.
- Metzger, J.O. and Bornscheuer, U. (2006) Lipids as renewable resources: Current state of chemical and biotechnological conversion and diversification. *Appl. Microbiol. Biotechnol.*, **71**, 13–22.
- Tilman,D., Hill,J. and Lehman,C. (2006) Carbon-negative biofuels from low-input high-diversity grassland biomass. *Science*, **314**, 1598–1600.

- Hoisington, D., Khairallah, M., Reeves, T., Ribaut, J.M., Skovmand, B., Taba, S. and Warburton, M. (1999) Plant genetic resources: What can they contribute toward increased crop productivity? *Proc. Natl. Acad. Sci. U.S.A.*, 96, 5937–5943.
- Keilwagen, J., Kilian, B., Özkan, H., Babben, S., Perovic, D., Mayer, K.F.X., Walther, A., Poskar, C.H., Ordon, F., Eversole, K. *et al.* (2014) Separating the wheat from the chaff – a strategy to utilize plant genetic resources from ex situ genebanks. *Sci. Rep.*, 4, e5231.
- Engels, J.M.M. and Maggioni, L. (2012) AEGIS: A regionally based approach to PGR conservation. In: Maxted, N, Dulloo, ME, Ford-Lloyd, BV, Frese, L, Iriondo, JM and Pinheiro, de Carvalho MAA (eds). Agrobiodiversity conservation: securing the diversity of crop wild relatives and landraces. CABI, Wallingford, pp. 321–326.
- Dias,S., Dullo,M.E. and Arnaud,E. (2012) The role of EURISCO in promoting use of agricultural biodiversity. In: Maxted,N, Dulloo,ME, Ford-Lloyd,BV, Frese,L, Iriondo,JM and Pinheiro,de Carvalho MAA (eds). *Agrobiodiversity conservation: securing the diversity of crop wild relatives and landraces.* CABI, Wallingford, pp. 270–277.
- Awika,J.M. (2011) Major cereal grains production and use around the world. In: Awika,JM, Piironen,V and Bean,S (eds). Advances in Cereal Science: Implications to Food Processing and Health Promotion, volume 1089 of ACS Symposium Series. American Chemical Society, Washington, DC, pp. 1–13.
- van Hintum, T. and Knüpffer, H. (2010) Current taxonomic composition of European genebank material documented in EURISCO. *Plant Genet. Res.*, 8, 182–188.
- Krajewski,P., Chen,D., Ćwiek,H., van Dijk,A.D., Fiorani,F., Kersey,P., Klukas,C., Lange,M., Markiewicz,A., Nap,J.P. *et al.* (2015) Towards recommendations for metadata and data handling in plant phenotyping. *J. Exp. Bot.*, 66, 5417–5427.
- Ćwiek-Kupczyńska, H., Altmann, T., Arend, D., Arnaud, E., Chen, D., Cornut, G., Fiorani, F., Frohmberg, W., Junker, A., Klukas, C. et al. (2016) Measures for interoperability of phenotypic data: minimum information requirements and formatting. *Plant Methods*. Accepted.
- Shrestha, R., Matteis, L., Škofič, M., Portugal, A., McLaren, G., Hyman, G. and Arnaud, E. (2012) Bridging the phenotypic and genetic data useful for integrated breeding through a data annotation using the crop ontology developed by the crop communities of practice. *Front. Physiol.*, **3**, e326.