

Global Access to Maize Germplasm Provided by the US National Plant Germplasm System and by US Plant Breeders

Bradley Kurtz*, Candice A. C. Gardner, Mark J. Millard, Thomas Nickson, and J. Stephen C. Smith

ABSTRACT

Access to high-yielding germplasm increases agricultural productivity. Plant Variety Protection (PVP) is the most globally used form of Intellectual Property Protection. Commercially available varieties protected solely by PVP can be accessed for further breeding within the country or region of protection. Unlike the practice in most other countries, the USDA has a policy of providing parental inbred lines of hybrids into the public domain following expiration of their protection by PVP. Parental lines and varieties protected by utility patents are also available in the public domain following expiration of protection. These distributions represent fresh opportunities for researchers, hybrid seed producers and plant breeders, nationally and internationally. As a contribution to the continuing debate over ownership and access to plant germplasm we report distributions of maize (*Zea mays* L.) by the US National Plant Germplasm System (NPGS). During 1988–2015 the NPGS distributed 251,926 packets to 7,582 requestors, fulfilling 10,432 orders. Distributions were primarily to US entities (87%), with 32,520 (13%) to a total of 79 foreign countries. Of the total NPGS maize distributions reported here, 45,968 (18%) were expired or off-PVP germplasm. We hope that access provided to this germplasm will act as a reminder that the primary benefit of the Multilateral System under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) is indeed that of having facilitated global access to germplasm and that this concept will remain an important guiding principle during further implementation of the Treaty.

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Abbreviations: CIMMYT, International Center for Maize and Wheat Improvement; IPP, Intellectual Property Protection; ITPGRFA, International Treaty on Plant Genetic Resources for Food and Agriculture; UPOV, International Union for the Protection of New Varieties of Plants; NPGS, National Plant Germplasm System; PVP, plant variety protection; USAID, US Agency for International Development.

MAIZE (*Zea mays* L.) is the most important food crop in the world in terms of total production, with over one billion metric tonnes (1,007,473,000) produced in 2014 (USDA FAS, 2015). Maize yields in the United States have increased more than fivefold from less than 1885 kg ha⁻¹ (30 bushels acre⁻¹) using open pollinated landraces to greater than 10,040 kg ha⁻¹ (160 bushels acre⁻¹) (Fig. 1) as a result of public and private investments in hybrids and use of improved agronomic practices (Smith et al., 2014a; USDA NASS, 2015). Most recent estimates of the proportion of yield gain attributable to breeding (genetic gain) during the era of single-cross maize hybrids in the United States (1963–present) range from 74% to 66–77% when grown in rain-fed and well-watered conditions, respectively (Smith et al., 2014a).

Maize is just one example of the numerous contributions plant breeders make globally in marshalling useful genetic diversity from a broader pool of available diversity in the service of agriculture and society (Frisvold et al., 2003; Day Rubenstein et al., 2005; DTZ, 2010; Smith et al., 2014b; Heisey and Day-Rubenstein, 2015). For example, the Green Revolution that began in the late 1960s

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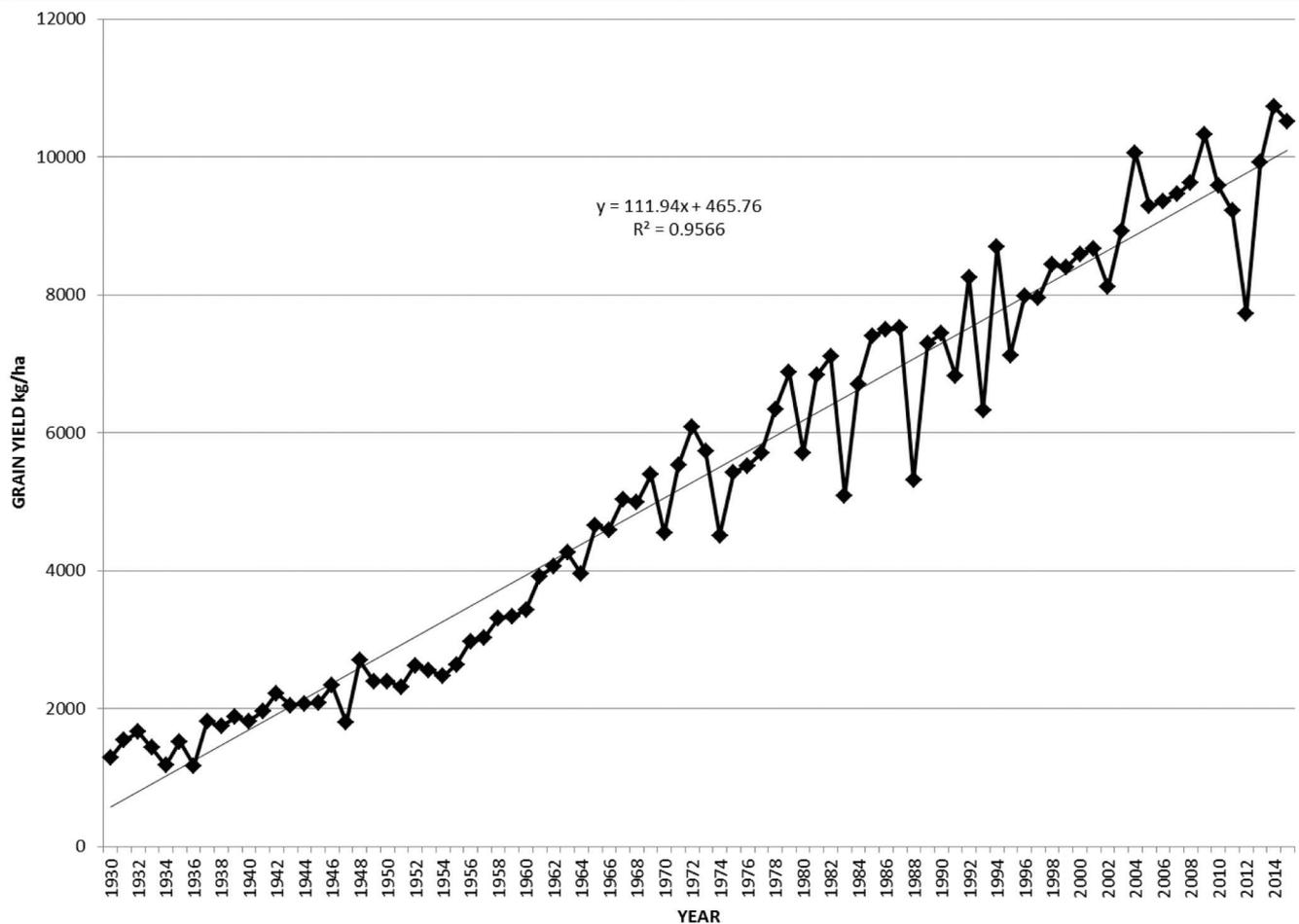


Fig. 1. US dent field corn yields 1930 to 2014 (USDA NASS, 2015).

led to increased yields and food security in Asia and Latin America using newly developed and more productive wheat (*Triticum* spp.) and rice (*Oryza* spp.) germplasm coupled with other inputs and improved management (Evenson and Golin, 2003; Stevenson et al., 2013). Results achieved through plant breeding further increased the demand for conservation and use of genetic diversity (Hajjar and Hodgkin, 2007; Ramirez et al., 2013). The productivity of US sorghum [*Sorghum bicolor* (L.) Moench] agriculture today is in very large part due to the introduction of new useful diversity from Africa as a result of the sorghum conversion program (Klein et al., 2008). Foreign germplasm has contributed significantly to cotton, maize, wheat and soybean productivity in China (Zeng, 1990; Li et al., 2006; Qin et al., 2006; Li et al., 2009; Yang et al., 2009; Li et al., 2011; Wang, 2013; Jia et al., 2014). These and other examples exemplify the multi-lateral dependencies that countries have, including those with centers of origin and diversity of cultivated species within their national borders, upon access to useful genetic diversity for crop improvement (Brown, 1984; Kloppenburg and Kleinman, 1988; Palacios, 1998; Fowler et al., 2000, 2001; Cassaday et al., 2001; Falcon and Fowler, 2002; Gepts, 2004; Brush, 2005; Frison and

Halewood, 2006; Ramirez et al., 2013; Wang, 2013). These interdependencies are likely to increase as agriculture relies more upon using genetic resource based solutions provided by plant breeders to allow production of healthy food, fiber, and fuel in ways that are environmentally sustainable and economically feasible for consumers and producers (Fujisaka et al., 2011; Ramirez et al., 2013). Most increases in demand for food are expected from developing countries (Rubenstein and Smale, 2004).

Many hold, and it is frequently stated, that a key overriding public goal must be to further increase crop yields by plant breeding to feed a growing world population. One approach will be to breed crops that yield more with less negative environmental impacts, including to help reduce pressures to bring additional lands under cultivation, a strategy described as “sustainable intensification” (Tilman et al., 2002; Cassman et al., 2003; Royal Society, 2009; Balmford et al., 2012). Other approaches that make less intensive use of chemical inputs may also be deployed. To be successful, all forms of agricultural practice will require continuous capabilities to allow farmers to adapt, including to implement new cultivation practices, be responsive to changing consumer demands and weather

patterns, and to be able to counter the continued evolution of weeds, pests and diseases (Swaminathan, 2009). These adaptive capacities will be dependent upon developing crop varieties with new arrangements of germplasm that provide the best fit for genotype x environment x management (Kresovich and McFerson, 1992; Tanksley and McCouch, 1997; Goodman, 1999; Hoisington et al., 1999; Skovmand et al., 2002; Dennis et al., 2008; Newton et al., 2010; Upadhyaya et al., 2010; Kilian and Graner, 2012; Economist, 2014). Consequently, as the future unfolds, the ability of global agriculture to be successful at meeting the diverse set of challenging goals required to achieve food and environmental security will likely be even more dependent upon multi-lateral access by plant breeders to a broad array of useful genetic diversity (Rubenstein and Smale, 2004; Hajjar and Hodgkin, 2007; Fujisaka et al., 2011; Halewood et al., 2013; Ramirez-Villegas et al., 2013).

Global Access to Plant Genetic Resources

Brown (1984) alerted the US seed production and plant breeding community about “the coming debate over ownership of plant germplasm.” Sullivan (2004) summarized global changes regarding the terms of access to plant genetic resources that had occurred during the prior 20 years, and which continue today. Unfortunately, international norms for germplasm exchange are shifting away from unencumbered access and movement. Total accessions acquired on an annual basis by all CGIAR centers peaked at 35,000 during 1985 but reached a low of 3,333 (received from outside sources) in 2009 (Halewood et al., 2013). The ‘highly-politicized’ nature of access and benefit-sharing was the major reason cited by gene bank managers for the decline in acquisitions (Halewood et al., 2013). With regard to access, only 17% of 126 member states provided any notification regarding which ex situ collections stored in their genebanks were in the multilateral system (Halewood et al., 2013). Bjørnstad et al. (2013) tested the ability to gain access to germplasm from 121 countries that are Contracting Parties to the ITPGRFA. Seeds were received from only 44 (36%) countries; 56 (46%) countries failed to respond, other requests failed due to loss of communication, non-existent seed, or because of contractual issues. Other, more recent developments do not yet provide clarity for future abilities to access PGRFA. There are ongoing discussions about bilateral access to genetic resources as a result of the entry into force of the Nagoya Protocol under the Convention on Biological Diversity on 12 Oct. 2014. Cultivated genetic resources in the form of landraces used on farms (in situ) are “likely not included automatically in the multilateral system” (Halewood et al., 2013). Uncertainties have also arisen with regard to the future implementation of the ITPGRFA due to the recognition by its Governing

Body of the need for new, effective funding mechanisms (International Treaty, 2015).

Currently, we see little that has changed since 1993 to 1998 (Shands, 1995, 2004; Williams, 2005) when it was recognized that germplasm globally, at least outside the United States, had become less accessible. For example, Shands (2004) noted:

“Four messages stand out relative to the current status of access and availability of plant genetic resources. First, the United States continues to manage the world’s largest national germplasm collection that is freely available to scientists the world over. Second, the new international treaties governing biodiversity are failing to facilitate access despite the clauses designed to ensure access. Third, intellectual property rights issues are entangled with access and utilization problems, and often present collectors with difficult or unacceptable choices. Fourth, there are valid reasons to encourage countries to provide broad access to their genetic resources. Such reasons include saving their collections, improving their agricultural economy, and promoting conservation.”

A global multilateral system has repeatedly been proven to be essential to save genetic resources that would otherwise be lost forever in the case of war or natural disaster. Examples include Cambodia, East Timor, Honduras, Nicaragua, Rwanda, Burundi, Somalia, Sudan, Romania, and Liberia (Imperial College, 2002) and, most recently, Syria (GCDT, 2015a). These experiences make the USDA National Plant Germplasm System (NPGS, 2015a), other national genebanks, and genebanks at international agricultural research centers even more important as resources that can enable access to a broad diversity of germplasm resources. It is important to reiterate that “access to genetic diversity in a multi-lateral system is by far the most important member benefit for all member states” (Halewood et al., 2013). As recently expressed by Mahmoud Sohl, Director General of the International Center for Agricultural Research in Dry Areas (ICARDA) located in Aleppo, Syria, “genebanks are not isolated treasure troves and shouldn’t be treated as such. Their power comes from the connections between them, and the worldwide network of genetic resources those connections create” (GCDT, 2015a).

As a positive contribution to discussions and future developments regarding multilateral access to germplasm, we believe it is important to recognize the extent of global access to genetic resources developed in the United States that is provided by the NPGS. The NPGS ranks globally as the second largest genebank when compared to the combined collections held under the auspices of the CGIAR (Jacob et al., 2015). However, among individual genebanks, the NPGS ranks globally as the world’s largest germplasm repository (FAO, 2010; Jacob et al., 2015).

Forms of Intellectual Property Protection and Access to Germplasm

Intellectual property protection (IPP) is a prerequisite for participation by the private or commercial sector in the development of new and improved plant varieties through plant breeding. Public sector plant breeders also utilize IPP, particularly when a degree of exclusivity is required to ensure mission goals are achieved (Cohen, 2000; JIC, 2009; SGRP, 2010). A brief review of the use plant breeders make of IPP is necessary to allow a full appreciation of the role that plant breeders seeking protection in the United States play nationally and globally in providing access to germplasm.

Plant breeders can utilize four types of intellectual property protection: (i) contracts, (ii) trade secrets, (iii) Plant Variety Protection (PVP) or Plant Breeders' Rights, and (iv) utility patents. In the United States, companies use several methods to protect intellectual property within the seed. These include language on the bag and other contracts to limit the use of molecular markers on the seed or resultant plant. This has the effect of protecting intellectual property in the seed, including trade secrets. The United States also provides PVP-type protection for breeders of non-tuberos asexually reproducing species under the 1930 US Plant Patent Act. Also, a hybrid crop per se also confers a measure of IPP because parental lines can be maintained as trade secrets and annual seed sales are encouraged due to the reduction in yield potential of the harvested F₂ generation seed.

On a global basis, the most widely used form of IPP for plant varieties is PVP. The International Union for the Protection of New Varieties of Plants (UPOV) prescribes basic rules for PVP and currently has 73 members (UPOV, 2015). Commercially released hybrids are usually protected by PVP or another form of sui generis protection (e.g., by the Plant Protection of Varieties and Farmers Rights Act in India; PPVFRA, 2001) and proprietary inbreds are maintained as trade secrets. Breeding using commercially available hybrid F₁ seed in country of protection is not restricted under PVP due to a breeder exception clause. However, breeders of hybrid maize have shown reluctance to breed from hybrids using the same heterotic patterns as they employ in order to maintain established heterotic patterns. There have been some, albeit important, examples of access to competitor hybrids via F₁ hybrid seed. This has especially been the case when those hybrids were made using inbreds related to one or more different heterotic pools thereby allowing the genetic integrity of different heterotic pools to be maintained. The ability to use newly developed inbreds subsequently to make commercial hybrids may be dependent upon their status in relation to the concept of essential derivation (UPOV, 1991). This is a potential issue when breeding in a country that has enacted PVP laws under UPOV 1991 or has otherwise adopted

an Essentially Derived Variety (EDV) clause into its PVP legislation. An abbreviated description of an EDV is an inbred line or variety that “is predominantly derived from the initial variety while retaining the expression of the essential characteristics that result from the genotype or combination of genotypes of the initial variety” (UPOV, 1991). For further information on EDVs see UPOV, (2013). Export of seed under PVP for further breeding is not allowed. However, export of derivatives bred via the breeder exception may be allowable depending upon country biodiversity laws. Access to parental lines of commercial hybrids during the commercial life of the hybrid should only occur as a result of agreement from the owner (ISF, 2012). In most countries, access to parental lines of hybrids following the period of their protection under PVP is also subject to agreement by the owner. In contrast, US federal regulations require seed of varieties under PVP, including their parental inbred lines, to be freely available to the public at the end of the protection period (USDA, 2006). The US government requirement for free availability after expiration of PVP differs from the practice in most countries where parental line germplasm is usually only publicly available on a special case-by-case basis under an agreement with the initial breeder.

Plant varieties per se are also eligible as patentable subject matter in the United States, and more recently in Canada, although this is not the practice in most other countries. In contrast to PVP, varieties that are (also) protected by utility patents in the United States are not available for use in breeding or seed production during the life of protection (maximum 20 years), unless usage is allowed by the owner. While seed of varieties protected by a utility patent can be accessed via a seed depository during the life of protection, such deposits do not provide “a grant of license...to infringe the patent” (Harney and McBride, 2007). At the expiration of patent protection the variety or inbred line enters the public domain because the depositor agrees to maintain seed in the public depository for the longer of 30 years, the life of the patent or 5 years after the most recent request.

Maize breeders usually decide to obtain IPP on an individual hybrid and parental line basis only after a decision has been made to advance a variety or hybrid to commercial status in order to efficiently focus resources required to file, obtain, and maintain intellectual property rights. Most, if not all parents of US commercial maize hybrids are protected by either, or both, PVP and utility patents. Varieties that contain patented traits are also themselves protected by utility patents under the scope of the trait patent and while some jurisdictions have an exception in patent law allowing further breeding, this is not the case in the United States. We estimate that similar numbers of utility patents and PVPs have been granted to US corn inbred lines. Release dates into the public

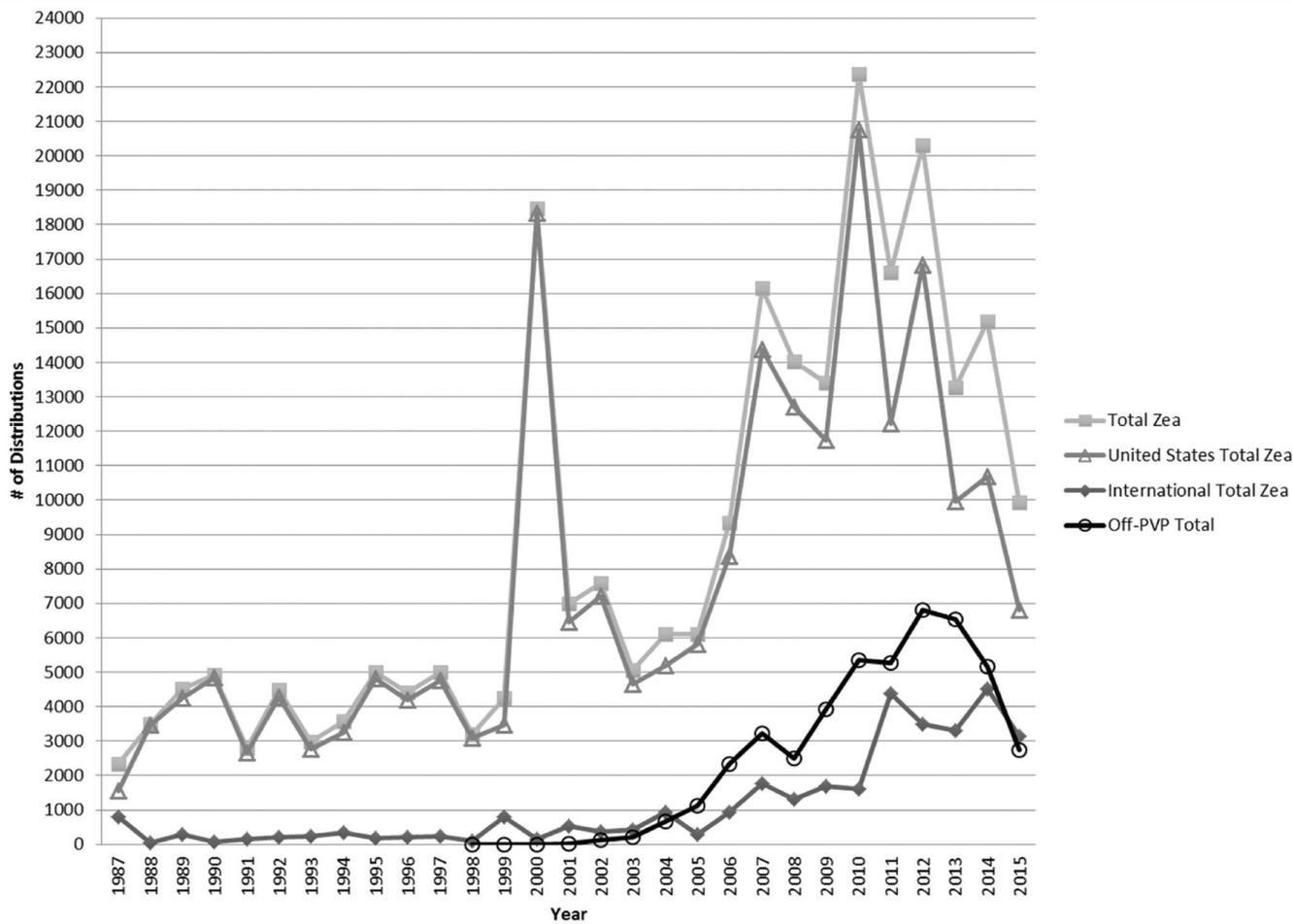


Fig. 2. Numbers of distributions (packets) of *Zea* spp, total, US, foreign and off-PVP inbred lines (US and foreign) by the USDA Northern Regional Plant Introduction Station from 1987 to 31 July 2015. (All data for 2015 are necessarily incomplete).

domain for inbred lines that have completed their full terms of PVP and utility patent protection (20 years from issuance for PVP; 20 years from filing for utility patents) will be close, usually within months.

Numbers of Accessions Stored by the NPGS

As of 1 Apr. 2015, the NPGS base collection comprised 591,085 samples including 426,562 seed accessions (NPGS, 2015b). This total includes over 8,000 genetic stock samples to maintain access for specific genes with usage primarily for basic research purposes. Inventories and distributions of the genetic stock samples are managed by the Genetic Stocks Center. We have chosen to omit genetic stock samples from further discussion because their purpose is neither for use in hybrid production, nor for the development of new inbreds and hybrid cultivars.

The distributing organization for maize accessions from the USDA NPGS is the Agricultural Research Service (USDA-ARS). The specific US distribution center for maize is the USDA-ARS North Central Regional Plant Introduction Station (NCRPIS) in Ames, IA. As of September 2015 and excluding special use genetic stocks,

the NCRPIS, held in storage 20,739 accessions of *Zea* spp. These were composed of (% of all maize accessions in parentheses) 227 Germplasm Enhancement of Maize accessions (1%), 370 off-PVP inbreds (2%), 2,550 other inbreds (12%), 17,153 maize populations (83%), 439 wild relatives of maize (2%) (data provided by Mark Millard at USDA-NPGS, 2015).

Distributions of Accessions Representing *Zea* spp.

As of 1 July 2015, the NCRPIS distributed 251,926 packets of maize fulfilling 7,582 requests and 10,432 orders between 1987 and 31 July 2015. Distributions were primarily to US entities (87%), with 32,520,705 (13%) distributions to other countries (Fig. 2). This global proportionality compares with a mean of approximately 75% US distributions across all crops distributed by the NPGS (P.K. Bretting personal communication, 2015). The geographic breadth of international distributions is truly global as illustrated by the number of foreign countries (79) to which materials have been sent (Supplemental Table S1). Most distributions were to US commercial companies, US government and

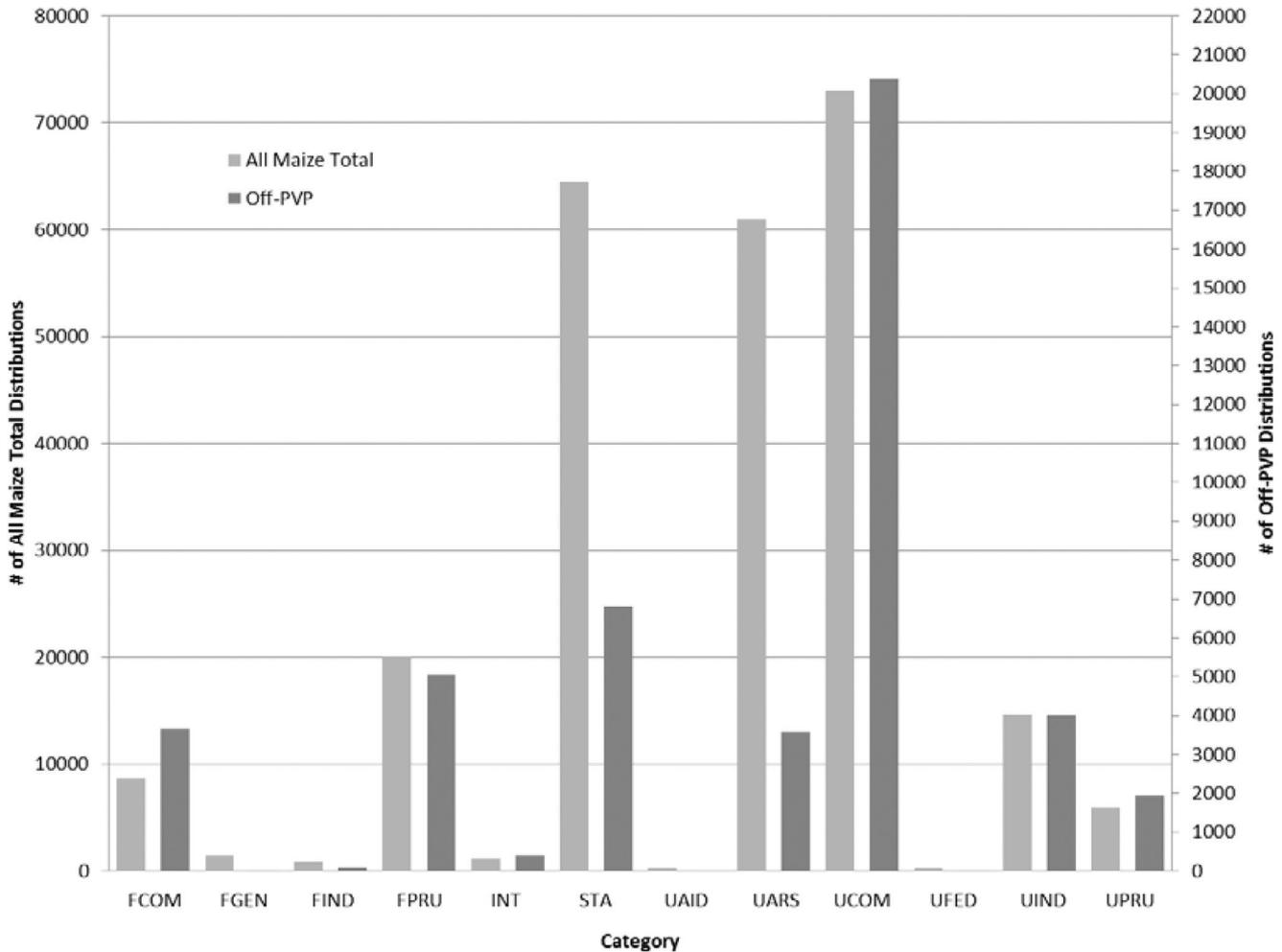


Fig. 3. Distribution of maize germplasm by the USDA Northern Regional Plant Introduction Station according to type of requestor. FCOM, foreign (non-US) company; FGEN, foreign genebank/genetic resource unit; FIND, foreign individual; FPRU, foreign non-commercial organization; INT, foreign CGIAR center; STA, US government and US universities; USAID, US Agency for International Development; UARS, US Agricultural Research Service; UCOM, US commercial; UFED, US federal agency (not ARS or AID); UIND, US individual; UPRU, US not for profit organization. Within category of requestor, distributions of all maize accessions are represented by the light-shaded histograms according to the scale of the left vertical axis while distributions for off-PVP inbreds only are represented by the dark-shaded histograms according to the scale of the right vertical axis.

US universities, and the US Agricultural Research Service (Fig. 3). Most foreign distributions of all maize accessions were to foreign non-commercial organizations and foreign companies (Fig. 3). Sixteen foreign countries accounted for 80% of foreign distributions, primary countries among these were (% of all distributions) China (2.4%), Canada (1.3%), and Germany (1.0%) (Supplemental Table S1).

Status of Accessions of Maize Inbred Lines with Expired Variety Protection

As of 30 June 2015, 365 accessions of off-PVP maize parental inbred lines were listed as available by the US Plant Variety Protection Office through the USDA Genetic Resources Information Network system (<http://www.ars-grin.gov/cgi-bin/npgs/html/pvplist.pl?>). Of these, the majority (358 or >98%) were field corn, 3 (<1%) were sweetcorn and 4 (1%) were popcorn. Available field corn

accessions were originally deposited by 29 entities, popcorn accessions by 4 entities, and sweet corn accessions by 2 entities. Organizations that had individually deposited >25 field corn accessions (numbers and % in parentheses) that are now available for distribution were DuPont Pioneer (126 or 35%), Holden Foundation Seeds (77 or 21%), and DeKalb (55 or 15%). Following mergers and acquisitions among companies Asgrow, Holden and DeKalb now represent Monsanto (205 or 56%), and Advanta, Funk Seeds Intl., Garst, Northrup King, and Novartis represent Syngenta (36 or 10%). Twenty-two (76%) entities individually deposited five or fewer of the accessions that are currently available for distribution.

Annual distribution numbers of off-PVP corn inbreds (all categories, although dent field corn represented >99% of distributions) began in 1998 and subsequently have risen significantly (Fig. 2). Annual distribution numbers

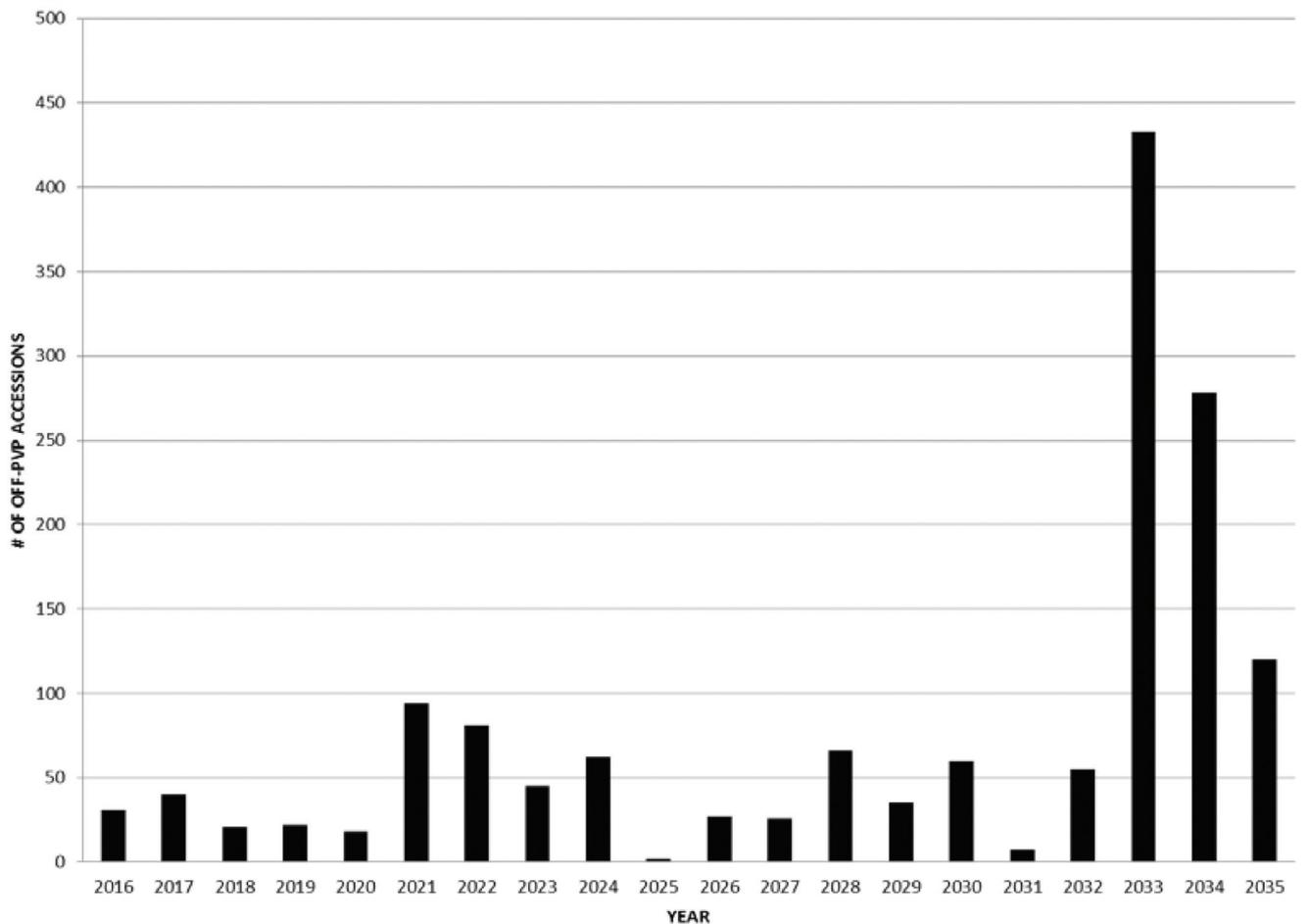


Fig. 4. Anticipated numbers of off-PVP corn inbreds available for distributions by the US Northern Regional Plant Introduction Station for US field, sweet, and popcorn inbred lines provided each PVP runs for the full (20 year) term. Field or dent corn inbred lines represent >99% of the distributions (see text). Data for 2035 are incomplete and approximate due to applications still pending as of 31 July 2015.

reached approximately 3,000 during 2005 to 2009, rising to approximately 5,500 during 2010 and subsequent years. From 1998 to 31 July 2015, the NCRPIS had distributed a total of 45,968 packets of corn inbred lines (including the categories of field or dent corn, popcorn, and sweetcorn although field dent corn represented >99% distributions), that had expired PVPs (Fig. 3). Distributions of off-PVP corn inbred lines now represent 18% of all maize distributions by the US NCRPIS. Most distributions of corn inbred lines with expired PVPs were to US commercial companies (20,371 or 44%), US government and US universities (6,830 or 15%), foreign non-commercial organizations (5,042 or 11%), US individuals (4,014 or 9%), foreign companies (3,656 or 8%), and the US Agricultural Research Service (3,592 or 8%) (Fig. 3). Many of off-PVP maize inbred lines have also been deposited in the back-up Svalbard global seed vault (GCDT, 2015b).

Future Distributions of Expired Corn Inbreds by the NCRPIS

As of September 2015 it is projected that during the next 20 years, 1443 to 1523 field maize inbred lines will be

made available by the NCRPIS as PVPs expire. A range is given because, as of September 2015, 83 inbreds were listed as PVP pending. If all currently pending PVPs are issued and all currently granted PVPs are allowed to run their full terms, then annual distributions during 2016 to 2035 will range from 2 to 433 with an annual mean of 76 (Fig. 4). The addition of one popcorn inbred line and two sweetcorn inbred lines are scheduled to be made available during the next 20 years.

DISCUSSION

Making expired-PVP parental inbred lines publicly available is important to broaden and to update the range of diversity available to researchers, hybrid seed producers, and developers of new inbred lines and hybrids on both a national and a global basis. The US system of implementing IPP and placing varieties and parental inbred lines into the public domain following expiration of their period of protection accomplishes these goals. Given the substantial flow of maize germplasm from the NPGS to international recipients, it is also reasonable to assume that numerous samples have also been further distributed by

these recipients under the terms of the Standard Material Transfer Agreement of the ITPGRFA (WIPO, 2006).

Breeding with commercial hybrids that are protected by PVP and not subject to patent protection is an activity that is still subject to biological (retaining heterotic groups), temporal and spatial restrictions, that is, germplasm is only available for further breeding in countries where varieties are protected by PVP (without utility patent coverage or expired utility patents) and during the life of a hybrid's commercial sales. Thus, commercial hybrids are not **globally** available for further breeding. Furthermore, in many other countries, with the exception of the United States, parental inbred lines of hybrids are generally never made publicly available after the commercial life of a hybrid. Thus, the US approach to IPP both incentivizes the investment and enables the advancement of research and breeding globally via germplasm access because utility patents and the US implementation of PVP prescribe full public access at the expiration of protection. These actions are consistent with the general intent and goal of intellectual property laws, which is to grant temporary exclusivity in exchange for enablement and public disclosure of the invention (Lence et al., 2005). Since protection terms for PVP and utility patents are the same and breeders in the United States generally seek protection under either or both systems simultaneously (just prior to commercialization), there is close synchrony for public availability and use when PVPs and utility patents have run their full terms.

While the off-PVP distributions represent a relatively small proportion (18%) of all maize distributions by the USDA-NCRPIS, they do represent a special category of great importance nationally and internationally, as further witnessed by the growth in annual distributions since 1998. The majority of off-PVP inbred lines have been used as parents of US commercial hybrids, including hybrids that were the most widely cultivated. Maize germplasm developed in the United States has also proven important as a resource to raise productivity in many other countries and regions including China, Europe, and South America. While not currently encompassing the full range of diversity represented by inbreds developed by US public breeding programs including by the public-private Genetic Enhancement of Maize program, see Fig. 4 in Romay et al. (2013), the off-PVP germplasm is still relatively diverse. For example, Hauck et al. (2014) reported that a set of 12 off-PVP maize inbreds were collectively only slightly less diverse than the 26 Core Diversity maize inbreds which themselves had been estimated to represent 75% of the diversity found in modern maize germplasm (Yan et al., 2009). Also included in this facilitated release of diversity are inbred lines developed from the landrace Iodent, which represents a third heterotic group compared to BSSS derivatives (Stiff-stalk) and Oh43-C103 Lancaster

types of Non-Stiff Stalks (Mikel, 2006, 2008, 2011; Mikel and Dudley, 2006; Nelson et al., 2008; Morales, 2013; Hauck et al., 2014).

In contrast to most other germplasm distribution categories, off-PVP materials can be exceptionally well characterized with declared pedigrees and of proven performance in US target production environments; many, if not most, can be expected to be well-adapted to temperate environments of other countries. Hauck et al. (2014) researched genetic diversity and agronomic performance data for numerous off-PVP maize inbred lines and line combinations and concluded that materials derived from former PVP lines will be important to maize breeding. Nevertheless, fully opening up opportunities afforded to the global maize research and breeding community by access to this germplasm will require determinations of which accessions can provide the most opportunities in further research, hybrid production, and breeding. Initial studies to help characterize these materials were based solely upon pedigree data available via the US PVP Office (Mikel, 2006, 2008, 2011; Mikel and Dudley, 2006). Molecular marker data (Romay et al., 2013) have enabled a perspective of the diversity of off-PVP US maize inbred lines within a global context of maize germplasm while Nelson et al. (2008) provided a marker comparison focused more on US maize germplasm. Morales (2013) reported detailed phenotypic and genetic data, including identification of stable QTL, for off-PVP inbreds showing of their combining abilities, agronomic strengths and weaknesses to enable their further and more widespread usage.

The potential of breeders to generate new, useful genetic diversity is hindered when incentives to invest in breeding are lacking and when access is limited. In turn, access is limited when genebanks harboring germplasm collections are not able to distribute accessions. During the next 20 years, approximately 1,500 additional maize inbred lines of proven performance will be made available by the USDA-NCRPIS to the public domain, including into the global public domain as a result of maize breeding conducted in the United States and protected under either US PVP law and/or utility patents (see also https://ag.purdue.edu/agry/rochefordlab/Pages/rl_exPVP-material.aspx). As discussions continue regarding terms of access to plant germplasm, we earnestly hope that facilitated access to germplasm will be recognized, once again, as the primary benefit of the Multilateral System under the ITPGRFA. The provision of access to germplasm must remain an important guiding principle in further implementation of the ITPGRFA (Halewood et al., 2013). No nation or region is self-sufficient for germplasm.

Supplemental Materials Available

Supplemental material is available with the online version of this article.

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