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Status of the *Medicago* germplasm collection in the United States

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Summary

Status of the *Medicago* germplasm collection in the United States

The United States collection of Medicago species is maintained by the USDA National Plant Germplasm System (NPGS) located at the Western Regional Plant Introduction Station in Pullman, Washington. The current collection contains a total of 7554 accessions with 4108 perennial accessions and 3,446 annual accessions. The beginning of the collection traces back to N.E. Hansen and his collection in Russia in 1898. Approximately a third of the collection has been evaluated for 13 diseases, seven insects, 26 agronomic traits, chromosome number, seven feed quality traits, and five stress tolerant traits. Core subsets have been developed for the perennial and annual species. Early in the history of alfalfa cultivar development, accessions within the collection were instrumental in expanding commercial production of alfalfa into the northern and eastern United States. In a survey of 500 US alfalfa cultivars released from 1990 to 1999, about 69% had lineage that could be traced back to accession brought in by early USDA plant introduction activities. Although the collection continues to support cultivar development in the United States, today, the majority of requested germplasm is intended for applied and basic research projects. The collection utilizes the advice and talents of an Alfalfa Crop Germplasm Committee (ACGC) that consists of 21 members representing federal, state and private interests. The NPGS Medicago species collection is an international treasure that requires continued vigilance to maintain the current collection, otherwise future collections, evaluations and enhancements would be of little value.

Key words: Alfalfa, core collections, evaluation, explorations, lucerne, Medicago.

Résumé

Situation de la collection de germoplasmes de Medicago aux Etats-Unis

Aux États-Unis, la collection d'espèces de Medicago est maintenue par le système national de conservation du matériel génétique végétal (National Plant Germplasm System, NPGS) de l'USDA à la Station régionale d'introduction des plantes de l'ouest, située à Pullman, Washington. La collection actuelle totalise 7554 accessions dont 4108 sont pérennes et 3446 annuelles. Le début de la collection remonte à la collecte effectuée par N.E. Hansen en Russie, en 1898. Environ le tiers de la collection a été évalué pour 14 maladies, 6 insectes, 25 caractères agronomiques, le nombre de chromosomes, 7 traits associés à la valeur nutritive et 5 à la tolérance aux stress. Des sous-ensembles ont été développés pour les espèces pérennes et les annuelles. Tôt dans l'histoire du développement des cultivars de luzerne, les accessions de la collection ont contribué à l'expansion de la culture de la luzerne dans le nord et l'est des États-Unis. Selon un relevé effectué sur 500 cultivars développés aux États-Unis entre 1990 et 1999, environ 69 % d'entre eux avaient des liens de parenté qui pouvaient remonter à des accessions résultant d'activités d'introduction menées antérieurement par l'USDA. Aujourd'hui, bien que la collection continue d'appuyer le développement de cultivars aux États-Unis, la majorité des demandes de germoplasme est faite dans le but d'effectuer des recherches fondamentales et appliquées. La collection bénéficie des avis et expertises d'un comité sur les germoplasmes de luzerne (Alfalfa Crop Germplasm Committee, ACGC) constitué de 21 membres représentant des intérêts nationaux, des états et du secteur privé. La collection d'espèces de Medicago du NPGS est un trésor international qui exige une vigilance soutenue afin de maintenir la collection actuelle, autrement les collections, évaluations et améliorations futures seront de moindre valeur.

Resumen

Estado de la Colección de Germenplasm de Medicago en los estado Unidos

La coleccion de la especie de Medicago de los Estados Unidos es mantenida por el USDA Sistema Germenplasma (NPGS) localizada en la Estacion Regional Occidental para la Introduccion de Plantas en Pullman Washington. La coleccion actual asciende a un total de 7,554 accesiones con 4,108 accesiones Perennes y 3,446 accesiones Anuales. El origen de la coleccion se puede remontar con N.E.Hansen y su coleccion en Russia en 1898. Aproximadamente una tercera parte de la coleccion a sido analizada contra 14 tipo de plagas , seis insectos, 25 razgos agronomicas, numero de cromosomas, siete rasgos de calidad y cinco rasgos de tolerancia a las tenciones. Establecimientos al corazon han sido desarrollados para los especies Perennes y Anuales.Temprano en el desarrollo del cultivo de la alfalfa, accesiones dentro de la coleccion han sido instrumentos en la expancion commercial de la produccion de alfalfa en el norte y el este de los Estados Unidos. En una encuesta de 500 cultivos publicados de 1990 a 1999 se encontro que cerca de un 69% de ellos tenian un linaje que puede ser trazado a accesiones de plantas importadas por actividades tempraneras de la USDA. Aunque la coleccion continua apollando el desarrollo del cultivo de la alfalfa en los Estados Unidos, hoy en dia la mayor parte de los pedidos de Germenplasma son dirijidos para la aplicacion de projectos de investigacion basica. La coleccion utiliza el consejo y talentos del comite del cultivo de Germenplasma de la alfalfa (ACGC) que contiene 21 miembros que representan intereses federales, estatales y privados. La coleccion de especies Medicago (NPGS) es un tesoro internacional que requiere vigilancia continua para mantener la coleccion actual, de otra forma colecciones futuras evaluaciones y mejoranientos tendrian poco valor.

Introduction

The genus *Medicago* is a member of the Legume family. According to Small and Jompe (1989) the genus contains 30 perennial and 60 annual species (Table 1). About 15 species are cultivated for various uses including: animal feed, soil improvement, cover crops, human nutrition, and ornamentals. Alfalfa or lucerne (*Medicago sativa* L. *sensu lato*) is a perennial species and the most

Table 1. The genus *Medicago* according to Small and Jomphe (1989), with geographic distribution, number of accessions per species in the NPGS collection, and conservation status† of each species as defined by Prosperi et al. (1996)

Species Subspecies	Geographic distribution	NPGS accession	Status†
Perennials			
M. arborea L.	S Europe, Turkey	38	B-Cult
M. archiducis-nicolai Širjaev	Central China, NE Tibet	0	Unk
M. cancellata M. Bieb.	European Russia	7	A
M. cretacea M. Bieb.	Russia, Former USSR	2	A
M. daghestanica Rupr. ex Boiss.	Dagestan	0	A
M. edeworthii Širjaev	Himalayas	3	A
M. hybrida (Pourret) Trautv.	France, Spain	1	A
M. lupulina L.	Europe, N Africa, Middle East, Asia	209	C-Cult
M. marina L.	S Europe, N Africa, Middle East, Crimea	20	B
M. papillosa Boiss.	Turkey, S Russia	8	A
ssp. *macrocarpa* (Boiss.) Urban	Turkey	0	A
ssp. *papillosa* Boiss.	Turkey, S Russia	1	A
M. pironae Vis.	Italy	4	A
M. platycarpa L. Trautv.	China, Mongolia, Central Asia	15	A
M. popovii Širjaev	Central Asia	1	A
M. prostrata Jacq.	Albania, E Europe, Italy	13	A
M. rhodopea Velen.	Bulgaria	2	A
M. rupestris M. Bieb.	Crimea, W Caucasus	0	A
M. ruthenica L. Trautv.	China, Korea, Mongolia, Russia	122	A
M. sativa ssp. *caerulea* Schmalh.	E. Turkey, Iran, Former USSR	77	B
ssp. *falcata* (L.) Arcangeli	S Europe, Former USSR		B-Cult
var *falcata* Archang.	N Eurasia	419	B-Cult
ssp. *glomerata* Balbis.	S Europe, N Africa, Caucasus	7	A
ssp. *sativa* (L.) L. & L.	Possible native range-Middle East, C Asia, now widely distributed	3042	C-Cult
ssp. x *varia* Martin	Europe, Iran, Syria, Turkey, Caucasus	287	B-Cult
ssp. x *tunetana* Murbeck	S Europe, N Africa, Caucasus	6	B-Cult
var *viscosa* Posp.	S Europe, N Africa, Caucasus	14	B-Cult
M. saxatilis M. Bieb.	Crimea	1	A
M. secundiflora Durieu	S Europe, N Africa	2	B
M. stasseri Greuter, Matthas & Risse	Crete	0	A
M. suffruticosa Raymond ex DC	France, Spain, Morocco	17	B
Annuals			
M. arabica (L.) Hudson	Europe, N Africa, Middle East, Crimea, Caucasus	79	C
M. arenicola (Huber-Mor.)	Turkey	0	?
M. astroites (Fisch. & Mey.) Trautv.	E Mediterranean	0	?
M. biflora (Griseb.) E Small	Turkey, Iran, S Trans-Caucasus	1	?
M. blancheana Boiss.	E Mediterranean	18	B
M. brachycarpa M. Bieb.	Turkey, Lebanon, Iraq, Transcaucasia	5	?
M. carica (Huber-Mor. & Širjaev) E Small	SW Anatolia	0	?
M. carstiensis Jacq.	E Europe	1	A
M. ciliaris (L.) Krocker	Mediterranean Basin, Iraq	64	C
M. constricta Durieu	E Mediterranean Basin, Iran, Iraq	52	B
M. coronata (L.) Bartal.	E Mediterranean Basin, Iran, Iraq	24	B
M. crassipes (Boiss.) E Small	Anatolia. Lebanon, N Iraq, W Iran	1	?
M. disciformis DC	Mediterranean Basin	50	B
M. doliata Carmign.	Italy, Spain, Algeria, Morocco	104	C
M. fischeriana (Ser.) Trautv.	Turkey, Iraq, Iran, European USSR	5	?
M. granadensis Willd.	Egypt, Israel, Syria, Turkey	13	B
M. halophila (Boiss.) E Small	S Anatolia	0	?
M. heldreichii (Boiss.) E Small	Turkey	0	?
M. heyniana Greuter	Greece	2	A
M. huberi E Small	SW Anatolia	0	?
M. hypogaea E Small	SE Mediterranean	0	A
M. intertexta (L.) Miller	W Mediterranean Basin	17	B
M. isthmocarpa (Boiss. & Bal.) E Small	C Anatolia	0	?
M. italica (Miller) Fiori	Mediterranean Basin	87	B-Cult
M. laciniata (L.) Miller	N Africa, Arabian peninsula, India, Pakistan, Afghanistan	136	B

M. lanigera Winkler & B. Fedtsch.	Afghanistan, Turkmenistan, Tajikistan	1	A
M. laxispira Heyn.	Iraq	0	A
M. lesinsii E Small	Mediterranean Basin	9	B-Cult
M. littoralis Rohde ex Lois	Mediterranean Basin, E Europe, Caucasus	173	B-Cult
M. medicaginoides (Retz.) E Small	SE Europe, SW USSR, Turkey, Iran, S and C Asia	1	?
M. minima (L.) Bartal.	Europe, N Africa, India., Russia	299	C
M. monantha (C.V. Meyer) Trautv.	Middle East, S and C Asia	38	?
M. monspeliaca (L.) Trautz.	W Europe, N Africa, E. Mediterranean, Jordan, Iraq, Iran, USSR, C Asia	12	?
M. murex Willd.	Mediterranean Basin	69	B-Cult
M. muricoleptis Tineo	France, Italy	8	A
M. noeana Boiss.	Iraq, Turkey	19	A
M. orbicularis (L.) Bartal.	Mediterranean basin, Middle East, Central Asia	322	C
M. orthoceras (Kar. & Kir.) Trautv.	Middle East, S and C Asia	0	?
M. ovalis (Boiss.) Širjaev	S Spain, Morocco	0	UNK
M. pamphylica (Huber-Mor. & Širjaev) E Small	S Anatolia	0	?
M. persica (Boiss.) E Small	Iran, Iraq	0	?
M. phrygia (Boiss. & Bal.) E Small	Turkey, Syria, Iraq, Iran	0	?
M. plicata (Boiss) Širjaev	Turkey	0	UNK
M. polyceratia (L.) Trautv.	W Mediterranean	10	?
M. polymorpha L.	Europe, N Africa, Middle East, Crimea, Caucasus, Central Asia	685	C-Cult
M. praecox DC	S and E Europe, Cyperus, Turkey, Crimea	23	B
M. radiata L.	Middle East, Russia, Central Asia	11	C
M. retrorsa (Boiss.) E Small	Afghanistan	0	?
M. rhytidiocarpa (Boiss. & Bal.) E Small	S Anatolia	0	?
M. rigida (Boiss. & Bal.) E Small	S Anatolia	0	?
M. rigidula (L.) All.	Mediterranean Basin, E Europe, Caucasus, Central Asia	148	C-Cult
M. rigiduloides E Small	E Mediterranean, Middle East	192	
M. rostrata (Boiss. & Bal.)	Turkey	0	?
M. rotata Boiss.	Cyprus, Iraq, Israel, Jordan, Lebanon, Syria, Turkey	21	B
M. rugosa Desr.	Mediterranean Basin	43	B
M. sauvagei Negre	Morocco	5	A
M. scutellata (L.) Miller	Mediterranean Basin, Southern Ukraine, Crimea	61	B-Cult
M. shepardii Post. ex Boiss.	Turkey	4	A
M. soleirolii Duby	France, Italy, Algeria, Tunisia	11	A
M. tenoreana Ser.	France, Italy, Yugoslavia	6	A
M. truncatula Gaertner	Mediterranean Basin, E Europe, Caucasus	320	C-Cult
M. turbinata (L.) All.	Mediterranean Basin	86	B

†Conservation status: A=endangered species, endemic or rare, very few available accessions in gene banks; B=species with threatened diversity due to a rapid modification of its ecosystem or due to its localization in regions subject to an important climate change, few available accessions; C=species widespread, large number of available accessions; Cult=genetically improved for agriculture; Unk or ?=unknown or undetermined (Prosperi et al. 1996).

important forage legume in North America. The annual species, referred to as medics, serve as important components in pastures in regions with Mediterranean climates. The United States collection of *Medicago* species is maintained by the USDA National Plant Germplasm System (NPGS) located at the Western Regional Plant Introduction (PI) Station in Pullman, Washington. Stephanie Greene is the curator of the collection. The current collection contains a total of 7554 accessions with 4108 perennial accessions and 3446 annual accessions (Germplasm Resources Information Network (GRIN), February 2002).

The objective of this study is to document the status of the NPGS *Medicago* collection and the approximately 100-year history of how the collection has been developed and utilized. The taxonomy of the genus *Medicago*, number of accessions in the collection, how the collection is preserved, what explorations have been accomplished, what types of evaluations have been conducted, how the collection has been utilized, and future priorities for the collection will be discussed.

In the early part of the last century, *Medicago* germplasm was obtained and selectively distributed by the USDA Office of Foreign Plant Introduction, in Beltsville, Maryland. In the 1940s the Regional Plant Introduction Stations were established to increase, evaluate, and distribute plant introductions. As plant introductions came into the United States, they were distributed to the four Regional PI Stations for evaluation. By 1949, the North Central Regional Plant Introduction Station in Ames, Iowa became the main site responsible for the increase, evaluation and distribution of alfalfa plant introductions. In 1971, the USDA National Plant Germplasm System was established, with the broader mission of preserving and encouraging the use of

germplasm as a guard against genetic erosion and crop vulnerability. In 1987 the *Medicago* collection was transferred from Ames, Iowa to the Western Regional Plant Introduction Station, in Pullman, Washington.

The collection can be divided into three components. The largest component contains *M. sativa* ssp. *sativa* consisting of cultivated (modern or obsolete cultivars), land races, ecotypes, naturalized and wild forms, comprising 42% of the total collection. Alfalfa relatives in the primary, secondary and tertiary gene pools account for 14% of the collection, although the majority of these accessions represent the closely related *M. sativa* ssp. *falcata* and *M. sativa* ssp. *varia* taxa (i.e. 10%). The annual *Medicago* species are well represented, with 2343 accessions representing 11 of the cultivated annual species, and 1103 accessions representing 44 non-cultivated annual species.

Based on the assessment of Prosperi et al. (1996) of the conservation status of *Medicago* species, the NPGS collection includes 23 species represented by 243 accessions that are considered to be endangered, endemic or rare species with very few accessions available in gene banks worldwide (Table 1). There are an additional 18 species represented by 998 accessions that are considered to be threatened due to a rapid modification of ecosystems or due to its localization in regions subject to an important climate change, of which there are few accessions available in worldwide gene banks (Table 1). Thus about 16% of the accessions in the NPGS *Medicago* collection represent vulnerable taxa. Although forage species have received a high priority for *in situ* conservation (IBPGR, 1984) the NPGS is currently not involved in the *in situ* conservation of the genus.

Germplasm preservation

Original seed and regenerated seed packets are kept at 3–5°C with 28% relative humidity in Pullman, Washington. A small sample of each accession is maintained at the National Seed Storage Laboratory in Fort Collins, Colorado to provide a safety back up. From 1979 to 1997, the majority of perennial accessions were regenerated using up to 200 plants germinated from original or the oldest existing seed lot, under isolation in cages and pollinated with leafcutter bees (*Megachile rotundata* F.). From 1987 to 1998, most of the annual medic species that are self pollinating were increased at Riverside, California. Regeneration of accessions newly acquired and those that have few seeds or require special handling are constantly ongoing.

Germplasm exploration

The beginning of the US *Medicago* germplasm collection traces back to N.E. Hansen and his collection in Russia in 1898. Accessions were collected directly in the field by plant explorers and scientists or obtained from agricultural research institutes, seed companies and US Embassy Agricultural Attaches. About 65 collection trips that focused on alfalfa germplasm have been made in the last 100 years (Table 2). The majority of accessions that are available today were received after 1940 when seed preservation became a priority. During the 1950s, 60s and 70s the collection grew by an average of 1400 accessions per year. During the 1980s, more than 4200 accessions were added to the collection. During the 1990s, the collection grew by 1400 accessions. The collection currently contains over 7000 accessions representing 90 species from 94 countries.

Current collection activities are based on the recent assessment of gaps in the collection determined by mapping longitude and latitude of collection sites (Figs. 1 and 2) and the lack of representation within the collection of rare species. Collection activities will follow the guidelines developed from the Convention on Biological Diversity. Exchanges of germplasm between germplasm collections in other countries will be used to fill gaps, and collection expeditions will be developed to other countries where there has been a lack of germplasm collected. Priority countries for future collections include Georgia, Crimea and the Southern Caucasus mountain regions of the former Soviet Union, the Himalayan region of India, south and northeast regions of China, Sudan, Egypt and the Arabian Peninsula, South Africa, Northern Kazakhstan, and adjacent Central Asian countries (i.e. Kyrgistan, Uzbekistan, Afghanistan), Iran and Iraq.

Evaluation of the collection

Since 1981, approximately one third of the perennial *Medicago* collection has been evaluated for 13 diseases (Table 3), seven insects (Table 4), chromosome number (Table 5), 27 agronomic traits (Table 5), seven feed quality traits (Table 6), and five abiotic stress tolerant traits (Table 7). All of the disease resistance, insect resistance, feed quality, and stress tolerance evaluations were conducted using standardized tests. The standardized tests were developed by research scientists in the federal government, universities and private industry and approved by the members of the North American Alfalfa Improvement Conference (North American Alfalfa Improvement Conference, 1999). These standardized tests are used by the alfalfa seed industry to evaluate and charac-

Figure 1. Origin of cultivated germplasm held in the NPGS collection.

Figure 2. Origin of wild *Medicago sativa* subsp. *sativa* germplasm held in the NPGS collection.

Table 2. Alfalfa germplasm collection trips made by US scientists in the last 100 years

Year	Collector	Country	No.[1]
1898	N.E. Hansen	Russia	10
1899	Lathrop, D. Fairchild	Peru, Argentina	2
1899	C. Sprenger	Italy	15
1906	N.E. Hansen	Europe, Siberia, E. Asia	35
1909	N.E. Hansen	Central Asia	2
1910	F. Meyer	Russia	6
1924	H.L. Westover	S. America	25
1925	D. Fairchild	N. Africa	21
1929	H.L. Westover	Russia	2
1930	H.L. Westover	Turkestan, Europe	5
1936	H.L. Westover; F.L. Wellman	Turkey; Iran	58
1937	W. Koelz	Afghanistan	9
1939	W. Koelz	Afghanistan	3
1940	W. Koelz	Iran	2
1948	J.R. Harlan	Turkey	78
1951	S.P. Kohli	India	28
1951	W.A. Archer	Ethiopia	20
1952	R.K. Godfrey	Turkey	37
1953	H.S. Gentry	Afghanistan	41
1954	E.E. Smith	Afghanistan	37
1954	H.S. Gentry; E.E. Smith	Pakistan	3
1955	H.S. Gentry	Iran	224
1955	J.L. Stephens	E. Africa	1
1956	H.S. Gentry; H.A. Schoth	Europe	26
1958	H.S. Gentry; H.A. Schoth	Dinaric Alps	35
1968	W.H. Skarda	USSR	34
1972	D.R. Dewey	Iran	11
1972	J.L. Schwendiman	Turkey, Iran	15
1973	I. Forbes Jr.; J.S. Gladstone	Morocco, Spain	53
1975	W.R. Lanford; B.L. Burson	Brazil	3
1976	P.K. Knowles	Afghanistan	1
1977	D.R. Dewey	USSR	56
1977	R.R. Smith; W.R. Landford	Greece, Italy, USSR	70
1978	D.R. Dewey; A.P. Plummer	USSR	1
1978	G.B. Polignando	Algeria	3
1980	M.D. Rumbaugh	N.W. America	35
1980	W.L. Graves	N. Africa	115
1981	J.H. Elgin; W.F. Lehman; M.D. Rumbaugh	Turkey; Bolivia, Peru, Ecuador	271
1982	M.D. Rumbaugh	Morocco, USSR	435
1983	M.D. Rumbaugh	Morocco	422
1984	M.D. Rumbaugh; N.L. Taylor	Romania	8
1986	D.A. Johnson	Pakistan, Nepal	42
1987	W. Kaiser	Spain	10
1988	K. Asay; N.L. Taylor,	USSR and Yugoslavia	22
1989	F.J. Muehlbauer; W.J. Kaiser; C.R. Sperling	Syria and Turkey	8
1989	D. Dewey; K.B. Jensen	USSR	11
1989	P. Beuselink; W. Graves; J. Kirkbride Jr.	Morocco	14
1990	K.F.M. Reed; B.S. Dear	USSR	11
1991	D. A. Johnson; M.D. Rumbaugh	Xinjiang, China	30
1991	L. Teuber; D. Mowry; T.A. Campbell	Mongolia	105
1993	G.A. Pederson; K.H. Quesenberry	S. Bulgaria	97
1993	D.A. Johnson; K.B. Jensen	N. Xinjiang, China	24
1993	G.R. Smith; C. Hoveland	Georgia	11
1994	D.A. Johnson; D.P. Sheehy	Mongolia	22
1994	W.L. Graves; P.J. Cunningham	N. Africa	9
1995	A.A. Afonin; M.D. Rumbaugh; W. Graves	Caucasus Mountains, Russia	6
1996	T. Lumpkin	Kazakhstan, Kirgizia, Uzbekistan	4
1996	W.J. Kaiser; R. Hannan	Bulgaria	25
1996	D.A. Johnson; D.P. Sheehy	China	15
1997	D.A. Johnson; L.K. Holzworth; T.A. Campbell; Berdahl Berdahl	China	12
1998	D.A. Johnson; D.P. Sheehy; M.E. Majerus; S.R. Winslow	Mongolia	25
1999	R.C. Johnson; H. Bockelman	Ukraine	19
2000	S.L. Greene	Russia	136

[1]Number of *Medicago* accessions collected, as determined from historical documents. Some accessions, especially those collected prior to 1940 are no longer available.

Table 3. Total number of perennial *Medicago* species evaluated for resistance to diseases and percent accession evaluated

Species	T	AN	AP	BW	DM	FS	LS	LP	PH	RH	SC	SS	SP	VW
M. cancellata	7	43	43	57	86	57	29	43	14	43	100	43	43	86
M. papillosa	8	0	0	0	0	0	0	0	0	0	25	0	0	0
M. pirioae	4	0	0	0	0	0	0	0	0	0	50	0	0	0
M. platycarpos	16	6	6	13	6	13	0	0	6	6	38	6	6	13
M. prostrata	13	0	0	0	0	0	0	0	0	0	39	0	0	0
M. ruthenica	118	1	1	1	1	1	0	1	1	1	16	1	1	1
M. sativa nsp. *tunetana*	5	0	0	0	0	0	0	0	0	0	40	0	0	0
M. sativa nsp. *varia*	337	21	46	34	32	34	12	18	25	26	34	18	18	57
M. sativa ssp. *caerulea*	82	34	44	49	48	49	29	31	21	9	22	31	31	54
M. sativa ssp. *falcata*	472	13	16	17	12	17	8	9	7	10	9	10	10	20
M. sativa ssp. *glomerata*	7	0	0	0	0	0	0	0	0	0	43	0	0	14
M. sativa ssp. *sativa*	2749	33	33	31	31	31	26	27	25	20	24	27	27	35
M. sativa var. *viscosa*	13	8	0	8	8	8	8	8	0	0	46	8	8	23
M. suffruticosa	13	0	0	0	0	0	0	0	0	0	15	0	0	0

T=total number of accessions evaluated; AN=anthracnose; AP=aphanomyces; BW=bacterial wilt; DM=downey mildew; FS=fusarium wilt; LS=common leaf spot; LP=lepto leaf spot; PH=phytophthera root rot; RH=rhizoctonia; SC=scleorotinia; SS=spring black stem; SP=stemphylium leaf spot; VW=verticilium wilt.

Table 4. Total number of perennial *Medicago* species evaluated for resistance to insect and percent accessions evaluated

Species	T	BA	LB	PA	PL	RC	SB	SA
M. cancellata	7	43	0	29	100	86	14	57
M. papillosa	8	0	0	0	13	25	0	0
M. pirioae	4	0	0	0	50	50	0	0
M. platycarpos	16	0	6	0	6	13	6	6
M. prostrata	13	0	0	0	0	0	0	0
M. ruthenica	118	0	1	0	2	2	0	1
M. sativa nsp. *tunetana*	5	0	0	0	38	0	0	0
M. sativa nsp. *varia*	337	28	6	28	49	37	8	32
M. sativa ssp. *caerulea*	82	49	0	49	21	50	6	49
M. sativa ssp. *falcata*	472	10	1	10	14	21	3	13
M. sativa ssp. *glomerata*	7	0	0	0	35	14	0	0
M. sativa ssp. *sativa*	2749	27	5	22	31	34	4	31
M. sativa var. *viscosa*	13	8	0	8	0	31	0	8
M. suffruticosa	13	0	0	0	0	0	0	0

T=total number of accessions evaluated; BA=blue aphid; LB=lygus bug; PA=pea aphid; PL=potato leafhopper; RC=root curculio; SB=snout beetle; SA=spotted alfalfa aphid.

terize new alfalfa varieties. Scientists in the federal government, universities and private industry conducted the tests and provided the data, which were imported into the Germplasm Resources Information Network (GRIN). GRIN is the system that holds all the data for the NPGS (http://www.ars-grin.gov/npgs).

The annual *Medicago* species were characterized primarily through agronomic and morphological field evaluations (Table 8). In addition, some disease resistance data are available for anthracnose resistance (O'Neill and Bauchan, 2000) (Table 8). These data were acquired as accessions were regenerated in Riverside, CA from 1988 to 1999 and as the annual medic core collection was developed in Beltsville, MD (Diwan et al. 1994a) and evaluated in six locations (Tucson, AZ; Athens, GA; Beltsville, MD; St. Paul, MN; Ithaca, NY; Logan, UT) across the U.S (Diwan et al. 1994b).

Development of core subsets

Core subsets have been developed for the perennial (Basigalup et al. 1995) and annual (Diwan et al. 1994a) *Medicago* species. A core subset is a small subset of accessions from the entire collection that: (1) contains most of the genetic variability that exists in the overall collection, (2) identifies duplications in the collection, (3) recognizes where there is a lack of germplasm representing a species or geographic location, (4) simplifies evaluation especially for difficult and/or expensive traits, and (5) increases the utilization of the collection. The core subsets utilized the evaluation data deposited in GRIN. Both core subsets used cluster analysis to aid in the selection of the accessions that would compose the core subset. The perennial *Medicago* species core subset, which contains 200 accessions, was selected from 1105 accessions that were field evaluated in Minnesota between 1989 and 1991. The annual *Medicago* species core subset contains 210 accessions selected from the evaluation of 1220 accessions in Maryland between 1990 and 1992. There are a number of advantages to core subsets for managing a germplasm collection, but the biggest advantage is the increased utilization of the collection.

Table 5. Total number of perennial *Medicago* species evaluated for agronomic traits and percent accessions evaluated

Species	T	CN	CS	CR	CD	CO	CW	CB	DM	DC	DS	FG	FM	FC
M. cancellata	7	0	43	43	43	43	43	43	43	43	43	43	43	0
M. papillosa	8	0	0	0	0	0	0	0	0	0	0	0	0	0
M. pirioae	4	0	0	0	0	0	0	0	0	0	0	0	0	0
M. platycarpos	16	0	6	6	6	6	6	6	6	6	6	6	6	0
M. prostrata	13	15	0	0	0	0	0	0	0	0	0	0	0	15
M. ruthenica	118	0	1	1	1	1	1	1	0	1	1	1	1	0
M. sativa nsp. *tunetana*	5	0	0	0	0	0	0	0	0	0	0	0	0	0
M. sativa nsp. *varia*	337	0	38	38	38	38	38	38	39	38	38	39	38	0
M. sativa ssp. *caerulea*	82	35	34	34	34	34	34	34	34	34	34	34	34	0
M. sativa ssp. *falcata*	472	56	12	12	12	12	12	12	12	12	12	12	12	36
M. sativa ssp. *glomerata*	7	0	0	0	0	0	0	0	0	0	0	0	0	0
M. sativa ssp. *sativa*	2749	2	32	32	32	31	32	32	31	32	32	32	32	0
M. sativa var. *viscosa*	13	15	0	0	0	0	0	0	0	0	0	0	0	0
M. suffruticosa	13	0	0	0	0	0	0	0	0	0	0	0	0	0

	GH	LS	MA	RE	RD	RN	RP	SV	SG	SP	SW	SL	TR	UL
M. cancellata	29	43	43	29	43	43	43	43	43	100	71	43	43	14
M. papillosa	0	0	0	0	0	0	0	0	0	100	63	0	0	0
M. pirioae	0	0	0	0	0	0	0	0	0	100	75	0	0	0
M. platycarpos	6	6	6	0	6	6	6	6	6	44	88	6	6	6
M. prostrata	0	0	0	6	0	0	0	0	0	92	100	0	0	0
M. ruthenica	0	1	0	1	1	1	1	1	0	93	95	0	1	1
M. sativa nsp. *tunetana*	0	0	0	0	0	0	0	0	0	60	100	0	0	0
M. sativa nsp. *varia*	21	39	39	18	38	38	38	39	39	61	82	39	38	7
M. sativa ssp. *caerulea*	28	34	34	17	34	34	34	34	34	55	87	34	34	6
M. sativa ssp. *falcata*	7	12	12	7	12	12	12	12	12	40	86	12	12	3
M. sativa ssp. *glomerata*	0	0	0	0	0	0	0	0	0	86	86	0	0	0
M. sativa ssp. *sativa*	19	32	31	18	32	32	32	31	31	53	83	31	32	6
M. sativa var. *viscosa*	0	0	0	0	0	0	0	0	0	77	62	0	0	0
M. suffruticosa	0	0	0	0	0	0	0	0	0	100	39	0	0	0

T=total number of accessions evaluated; CN=chromosome number; CS=crown stem diameter; CR=crown branching; CD=crown depth; CO=crown origin; CW=crown width; CB=crown budding; DM=days to maturity; DC=determinate tap root percentage; DS=determinate tap root position; FG=fall growth; FM=fibrous root mass; FC=flower colour; GH=growth habit; LS=leaf size; MA=maturity; RE=recovery after cutting; RD=root diameter; RN=root number; RP=root position; SV=seedling vigour; SG=seedling year productivity; SP=seed production; SW=seed weight; SL=stem–leaf ratio; TR=tap root; UL=unifoliate internode length.

Table 6. Total number of perennial *Medicago* species evaluated for feed quality traits and percent accessions evaluated

Species	T	AL	AS	CL	CS	NL	NS	PB
M. cancellata	7	43	43	43	43	43	43	29
M. papillosa	8	0	0	0	0	0	0	0
M. pirioae	4	0	0	0	0	0	0	0
M. platycarpos	*16*	*6*	*6*	*6*	*6*	*6*	*6*	*0*
M. prostrata	13	0	0	0	0	0	0	0
M. ruthenica	118	0	0	0	0	0	0	0
M. sativa nsp. *tunetana*	5	0	0	0	0	0	0	0
M. sativa nsp. *varia*	337	39	39	39	39	39	39	7
M. sativa ssp. *caerulea*	82	34	34	34	34	34	34	6
M. sativa ssp. *falcata*	472	12	12	12	12	12	12	2
M. sativa ssp. *glomerata*	7	0	0	0	0	0	0	14
M. sativa ssp. *sativa*	2749	31	31	31	31	31	31	6
M. sativa var. *viscosa*	13	0	0	0	0	0	0	23
M. suffruticosa	13	0	0	0	0	0	0	8

T=total number of accessions evaluated; AL=acid detergent fibre of leaves; AS=acid detergent fibre of stems; CL=Crude protein of leaves; CS=crude protein of stems; NL=neutral detergent fibre of leaves; NS=neutral detergent fibre of stems; PB=bypass protein.

Table 7. Total number of perennial *Medicago* species evaluated for abiotic stress traits and percent accessions evaluated

Species	T	AS	FD	SG	SS	WI
M. cancellata	7	43	43	57	29	43
M. papillosa	8	13	0	0	0	0
M. pirioae	4	50	0	0	0	0
M. platycarpos	16	25	6	6	6	6
M. prostrata	13	23	0	0	0	0
M. ruthenica	118	6	0	1	1	0
M. sativa nsp. *tunetana*	5	40	0	0	0	0
M. sativa nsp. *varia*	337	18	39	51	41	39
M. sativa ssp. *caerulea*	82	37	34	45	37	34
M. sativa ssp. *falcata*	472	9	12	16	14	12
M. sativa ssp. *glomerata*	7	29	0	14	0	0
M. sativa ssp. *sativa*	2749	18	32	36	21	31
M. sativa var. *viscosa*	13	31	0	15	0	0
M. suffruticosa	13	15	0	0	0	0

T=total number of accessions evaluated; AS=acid soil tolerance; FD=frost damage; SG=germination of seedlings in salt; SS=tolerance to salt tolerance; and WI=winter injury.

Utilization

Early in the history of alfalfa cultivar development, accessions within the germplasm collection were evaluated and selections made of the best, which were increased and released as cultivars (Rumbaugh, 1979, 1982, 1991; Barnes et al. 1977). 'Turkestan', 'Cossack', 'Ladak', and 'Nemastan' were early plant introductions, which became cultivars between 1871 and 1920. This trend of selection of plant introductions has continued, although at a much reduced frequency. The variety 'Deseret', a selection from PI 279958, was released as recently as 1977 (Pederson and Griffin, 1977). All US alfalfa cultivars can be traced to nine germplasm sources: 'Falcata', 'Varia', 'Turkestan', 'Flemish', 'Ladak', 'Chilean', 'Peruvian', 'Indian", and 'African' (Barnes et al. 1977). With the exception of the 'Chilean' and many of the 'Varia' sources, these germplasm sources were introduced into the US through the early efforts of the USDA Plant Introduction Office, and can be traced to specific PI numbers.

A majority of the modern alfalfa cultivars have arisen predominantly from pre-existing cultivars or germplasm pools, not from accessions within the collection. Nevertheless, a recent survey of the lineage of modern alfalfa cultivars revealed that 46 PI accessions were directly involved as parents for cultivars that were released with many of these early cultivars becoming 'foundation' cultivars that supported further cultivar development. There were 146 PIs directly involved as parents for germplasm releases. A close scrutiny of 500 cultivars released in the last 100 years disclosed that about 70% of the cultivars released have PI parents, grandparents or great-grandparents. Germplasm released by Sorensen et al. (1985, 1986) derived from PIs and Shade and Kitch (1986) included three perennial species, *M. glandulosa*, *M. glutinosa*, and *M. prostrata*, which are recognized as the sources of glandular hairs that have been transferred to alfalfa to provide tolerance to the potato leafhopper in the cultivar 'Trailblazer' released in 1998 (Association of Official Seed Certifying Agencies, 1998). The lag time between release of a new germplasm source and the release of a new cultivar is typified in this example. Although the NPGS collection has been utilized to develop alfalfa varieties in the US, direct use of PIs occurred early. Although cultivars that contain lineage from PIs are used in cultivar development today, direct use of PIs has been limited in the development of cultivars over the last two decades.

A recent survey of the utilization of the *Medicago* collection reveals that the collection is used extensively to support basic and applied research. Between 1993 and 1997 a total of 12,800 seed packets were distributed from the US collection for 229 requests. Scientists from US universities were responsible for almost half of the seed requests. The remaining requests for perennial species were split almost equally between the United States Department of Agriculture and the Agricultural Research Service scientists, private breeding companies and foreign scientists. Private company requests accounted for only 4% of the annual *Medicago* species requested. When collection use was examined by taxa, and size of collection factored out, use of germplasm representing the secondary and tertiary alfalfa gene pools has been higher on average than use of the alfalfa collection in the last 5 years. However, 5400 seed packets were distributed from the *M. sativa* ssp. *sativa* collection. Requests for non-cultivated annual species has been greater than for the perennial species and is probably due to requests for the annual medic core collection. Five percent of the orders for perennial species were for the alfalfa core collection, while 13% of orders for annual species were for the core subset. The majority of requested germplasm was intended for applied and basic research projects. A substantial amount of germplasm was requested for screening by crop breeding programs.

Future priorities

The NPGS *Medicago* species collection still faces many challenges including the increasing size of the collection and shrinking budgets to maintain and preserve the collection. However, the collection utilizes the advice and talents of an Alfalfa Crop Germplasm Committee (ACGC) that consists of 21 members representing federal, state and private interests. There are representatives of several scientific disciplines including: breeding, genetics, cytoge-

Table 8. Total number of annual *Medicago* species evaluated for agronomic traits and percent accessions evaluated

Species	T	SW	AN	BA	BW	DF	DP	FR	GS	GH	IL	LL	LW	PH	PS	S	PR	VP	W
M. arabica	79	95	3	95	38	89	3	1	80	85	39	43	43	40	37	3	1	89	86
M. blancheana	18	100	39	100	100	39	100	100	95	72	100	100	100	100	100	100	95	100	72
M. ciliaris	64	98	9	84	47	80	16	9	64	84	47	47	47	47	47	16	9	80	73
M. constricta	52	94	6	87	56	71	10	10	50	85	58	58	58	56	56	13	8	71	60
M. coronata	24	100	8	100	13	100	8	4	96	100	13	13	13	13	13	8	4	100	100
M. disciformis	50	98	8	100	54	100	22	18	96	96	54	54	54	54	54	22	18	100	100
M. doliata	104	95	2	91	278	90	5	8	70	91	26	26	26	27	27	6	7	88	87
M. fischeriana	5	80	0	40	0	40	0	0	20	40	0	0	0	0	0	0	0	40	40
M. granadensis	13	92	31	100	92	100	23	8	100	100	85	92	92	92	92	23	0	100	100
M. heyniana	2	100	50	100	100	50	50	100	100	100	100	100	100	100	100	100	100	100	0
M. intertexta	19	68	32	100	100	84	21	0	63	100	100	100	100	100	100	21	0	84	79
M. italica	87	95	10	71	34	71	20	20	64	86	34	34	34	34	34	20	18	76	66
M. laciniata	136	93	7	88	38	88	37	35	81	86	38	38	38	37	39	37	34	88	85
M. lanigera	1	100	100	100	100	100	100	100	100	100	0	0	0	100	100	100	0	100	100
M. lesinsii	9	100	22	100	33	100	11	11	89	100	33	33	33	33	33	22	11	89	89
M. littoralis	173	98	4	68	29	61	12	20	40	68	28	29	29	29	28	16	18	53	42
M. lupulina	209	92	7	61	29	56	15	11	44	61	17	24	24	30	29	15	11	56	49
M. minima	299	94	1	92	31	88	3	2	84	87	16	32	32	31	32	37	3	88	6
M. murex	69	88	7	93	43	88	6	3	83	86	42	42	42	39	42	7	3	88	86
M. muricoleptis	8	100	13	100	88	88	63	0	0	100	88	88	88	88	88	0	0	88	88
M. noeana	19	74	11	100	68	100	16	0	95	100	47	74	74	74	47	11	0	100	100
M. orbicularis	322	93	2	81	25	73	13	11	55	81	26	26	26	25	25	14	13	73	65
M. polymorpha	685	95	5	91	31	87	22	22	46	90	29	30	30	31	29	24	21	87	78
M. praecox	23	83	9	91	74	87	17	83	87	13	61	61	4	57	43	17	9	83	83
M. radiata	11	100	36	73	64	55	36	18	18	73	45	55	55	73	64	36	9	55	18
M. rigidula	148	91	2	91	24	76	83	4	2	78	68	16	23	22	24	4	1	83	82
M. rigiduloides	192	93	2	86	20	48	79	1	66	74	9	19	19	18	20	1	1	79	76
M. rotata	21	86	29	95	95	95	90	86	67	95	95	95	95	95	95	90	90	95	86
M. rugosa	43	81	26	91	63	88	35	14	79	91	63	63	63	63	60	37	19	88	86
M. sauvagei	5	100	40	100	80	100	0	40	100	100	20	60	60	60	60	40	0	100	100
M. scutellata	61	90	28	95	61	95	44	34	77	90	59	59	59	46	57	44	33	95	80
M. shepardii	11	36	0	36	18	36	0	0	36	36	18	18	18	0	9	0	0	36	36
M. soleirolii	11	100	18	64	64	18	9	0	18	64	55	55	55	18	55	9	0	27	18
M. tenoreana	6	100	17	100	33	100	17	0	100	100	0	17	17	17	17	17	0	100	100
M. truncatula	320	100	3	84	18	80	6	8	69	82	17	18	18	13	17	8	7	78	73
M. turbinata	86	94	6	83	26	81	8	8	76	79	21	27	27	14	19	8	7	81	79

T=number of Accessions; SW=100 seed weight; AN=anthracnose resistance; BA=biomass among species; BW=biomass within species; DF=days to flower; DP=days to full pod; FR=flowers/raceme; GS=grams of seed produced; GH=growth habit; IL=internode length; LL=leaflet length; LW=leaflet width; PH=plant height; PS=plant spread; S=pod spines; VP=visual pod production; W=winter vigor.

netics, entomology, pathology, physiology, microbiology, and molecular biology. In addition there is geographic representation of researchers from the major alfalfa growing areas of the US.

Recently the ACGC developed a set of priorities for the collection in four main areas: seed regeneration, germplasm collection, germplasm evaluation, and germplasm enhancement. Although the seed regeneration of almost all the collection has been completed, the need remains to: (1) regenerate accessions requiring special care/handling, (2) obtain baseline seed viability data, (3) store original seed and regeneration seed lots at -18°C, (4) deal with the backlog of new accessions coming into the collection and old accessions stored at the National Seed Storage Laboratory in Fort Collins, Colorado, (5) identify duplicate accessions, and (6) verify that the regeneration procedures are adequate. The greatest needs for new collections are for the wild perennial species in the secondary gene pool, especially those species that are considered threatened. A set of descriptors for all accessions, especially all *M. sativa* accessions needs to be completed. The currently established core subsets should be reevaluated once descriptor data has been obtained on the entire collection. Accession classification based on molecular markers needs to be accomplished and molecular data compared with classifications based on morphological and ecogeographic descriptors. In addition, evaluations that can broaden the use of alfalfa need to be carried out. National and regional germplasm pools should be developed as a germplasm enhancement tool to encourage the use of accessions in the collection by plant breeders.

The NPGS *Medicago* species collection is an international treasure that requires continued vigilance in maintaining the current collection, otherwise future collections, evaluations and enhancements would be of little value.

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