Table S1. Studies on *Astragalus* in which the germination data did not meet the requirements for inclusion in our meta-analysis, but they indicated that seeds of *Astragalus* have (or seem to have) physical dormancy or combinational dormancy (*A. amphioxys* and *A. cottonii*).

|  |  |  |
| --- | --- | --- |
| *Astragalus* species | Section | Reference |
| *A. accidens* | *Pruniformes* (Jones) Barneby | Spellenberg (1976) |
| *A. allochrous* | *Inflati* Gray | Head (1957) |
| *A. alopecuroides* | *Alopecuroidei* DC. | Merlo and Alemán (1996); Kožuharova *et al*. (2010) |
| *A. alpinus*  | *Komaroviella* Gontsch. | Flüeler (1992) |
| *A. amphioxys* | *Argophylli* Gray | Spellenberg (1976) |
| *A. andersonii* | *Hamosi* Jones | Head (1957); Spellenberg (1976) |
| *A. aquilanus*  | *Dissitiflori* DC. | Di Martino *et al*. (2015) |
| *A. arequipensis* | *-*a | Ledingham and Pepper (1973) |
| *A. arnottianus* | *-*a | Ledingham and Pepper (1973) |
| *A. arrectus* | *Reventi-Arrecti* Jones | Head (1957) |
| *A. arthurii* | *Hamosi* Jones | Head (1957) |
| *A. anxius*  | *Micromerii* Barneby | Meinke and Kaye (1992) |
| *A. beckwithii* | *Inflati* Gray | Head (1957) |
| *A. bellus* | *-*a | Ledingham and Pepper (1973) |
| *A. bergii*  | *-*a | Ledingham and Pepper (1973) |
| *A. brevidens*  | *Uliginosi* Gray | Zarekia *et al*. (2014) |
| *A. brauntonii*  | *Brauntoniani* Barneby | Fotheringham and Keeley (1998); [https://calscape.org/Astragalus-brauntonii-(Brauton’s-Milkvetch)?srchcr=sc57729a6625ca9](https://calscape.org/Astragalus-brauntonii-%28Brauton%27s-Milkvetch%29?srchcr=sc57729a6625ca9), accessed 4 January 2019) |
| *A. burkartii*  | *-*a | Ledingham and Pepper (1973) |
| *A. campylotrichus* | *Heterodontus* Bunge | Rosbakh et al. (2020) |
| *A. canadensis*  | *Uliginosi* Gray | Green and Curtis (1950); Head (1957); Hung and Xie (2008); Townsend and McGinnies (1972b); Sorensen and Holden (1974) |
| *A. caraganae*  | *Astragalus* L. | Moghadam *et al*. (2012) |
| *A. cariensis*  | *Incani* DC. | Erisen *et al*. (2011) |
| *A. carinatus* | *-*a | Ledingham and Pepper (1973) |
| *A. cemerinus*  | *Microphysa* Bunge | Riahi and Zarre (2009) |
| *A. chamaeleuce* | *Argophylli* Gray | Head (1957) |
| *A. cibarius* | *Argophylli* Gray | Head (1957) |
| *A. clerceanus* | *Craccina* Bunge | Rosbakh et al. (2020) |
| *A. collinus* | *Collini* Jones | Head (1957) |
| *A. congdonii* | *Hamosi* Jones | Head (1957) |
| *A. conjunctus* | *Reventi-Arrecti* Jones | Head (1957) |
| *A. cottonii*  | *Hemiphragmium* (Koch) Bunge | Kaye (1997) |
| *A. crotalariae* | *Preussiani* (Jones)Barneby | Spellenberg (1976) |
| *A. cruckshanksii* | *-*a | Ledingham and Pepper (1973) |
| *A. crypticus* | *-*a | Ledingham and Pepper (1973) |
| *A. cryptobotrys* | *-*a | Ledingham and Pepper (1973) |
| *A. curvicaulis* | *-*a | Ledingham and Pepper (1973) |
| *A. cusickii* | *Inflati* Gray | Head (1957) |
| *A. danicus* | *Hypoglottidei* DC. | Rosbakh et al. (2020) |
| *A darumbium* | *-*a | Ledingham and Pepper (1973) |
| *A. dasyanthus*  | *Caprini* DC. | Kožuharova *et al*. (2010) |
| *A. demavendicus*  | *Incani* DC. | Riahi *et al*. (2003) |
| *A. desereticus*  | *Argophylii* Gray | Hotze (2011) |
| *A. devesae*  | *Platyglottis* Bunge | Ribeiro *et al.* (2019) |
| *A. diaphanous* | Undetermind | Head (1957) |
| *A. diphacus* | *Diphaci* (Rydb.) Barneby | Spellenberg (1976) |
| *A. distinens* | *-*a | Ledingham and Pepper (1973) |
| *A. douglasii* | *Inflati* Gray | Spellenberg (1976) |
| *A. edmondstonei* | *-*a | Ledingham and Pepper (1973) |
| *A. effusus* | *Onobrychoidei* DC. | Zarekia *et al*. (2014) |
| *A. eremeticus* | *Reventi-Arrecti* Jones | Head (1957) |
| *A. ervoides* | *Miselli* Barneby | Spellenberg (1976) |
| *A. falcatus*  | *Uliginosi* Gray | Townsend and McGinnies (1972a, b) |
| *A. flexuosus* | *Scytocarpi* Gray | Spellenberg (1976) |
| *A. frigidus*  | *Phaca* Bunge | Flüeler (1992); Rosbakh et al. (2020) |
| *A. galegiformis*  | *Galegiformes* Gray | Townsend and McGinnies (1972a, b) |
| *A. garbancillo* | *-*a | Ledingham and Pepper (1973) |
| *A. geminiflorus* | *-*a | Ledingham and Pepper (1973) |
| *A. giganteus* | *Gigantei* Barneby | Spellenberg (1976) |
| *A. glycophyllos* | *Glycyphyllos* (Stev.) Bunge | Rosbakh *et al*. 2020) |
| *A. granatensis*b | *Hypoglottidei* DC. | Trillo and Matilla (1993a,b); Lorite *et al.* (2007) |
| *A. gypsodes* | *Sarcocarpi* Gray | Head (1957) |
| *A. humistratus* | *Humistrati* (Jones) Barneby | Spellenberg (1976) |
| *A. hypsogenus* | *-*a | Ledingham and Pepper (1973) |
| *A. inflexus* | *Argophylli* Gray | Head (1957) |
| *A. jaegerianus* | *Jaegeriani* Barneby | Rundel *et al*. (2012) |
| *A. joergensenii* | *-*a | Ledingham and Pepper (1973) |
| *A. karelinianus* | *Dissitiflori* DC. | Rosbakh *et al*. (2020) |
| *A. laguroides* | *Laguropsis* Bunge | Rosbakh *et al*. (2020) |
| *A. latifolius*  | *Incani* DC. | Riahi *et al*. (2003) |
| *A. lentiginosus*  | *Inflati* Gray | Head (1957); Pavlik and Barbour (1988); Glenn (2009); Sankary and Barbour (1980); Ziemkiewicz and Cronin (1981) |
| *A. limariensis* | *-*a | Ledingham and Pepper (1973) |
| *A. lonchocarpus*  | *Lonchocarpi* Gray | Karron (1989) |
| *A. longidentatus*  | *Harpilobus* Bunge | Merlo and Alemán (1996) |
| *A. melanostachys*  | *Brachycarpus* Boriss. | Ashraf and Gohil (1988) |
| *A. membranaceus*c | *Cenantrum* Koch | Duan *et al*. (2005); Shi *et al*. (2014) |
| *A. micranthellus* | *-*a | Ledingham and Pepper (1973) |
| *A. minimus* | *-*a | Ledingham and Pepper (1973) |
| *A. molissimus*  | *Mollissimi* Gray | Head (1957); Spellenberg (1976); Melgoza-Castillo (1995); Castillo *et al*. (2003) |
| *A. neglectus*  | *Neglecti* (Rydb.) Barneby | Bowles *et al*. (1993) |
| *A. nezaketae*  | *Incani* DC. | Erisen *et al*. (2010) |
| *A. nutans* | *Inflati* Gray | Spellenberg (1976) |
| *A. onobrychis* | *Onobrychoidei* DC. | Rosbakh *et al*. (2020) |
| *A. oocalycis* | *Oocalyces* Barneby | Spellenberg (1976) |
| *A. orbiculatus* | *Myobroma* (Stev.) Bunge | Rosbakh *et al*. (2020) |
| *A. osterhoutii*  | *Pectinati* Gray | Karron (1989) |
| *A. oxyphysus* | *Densifloii* (Rydb.) Barneby | Spellenberg (1976) |
| *A. pachypus* | *Podo-Sclerocarpi* Gray | Head (1957) |
| *A.* *paposanus* | *-*a | Ledingham and Pepper (1973) |
| *A. parodii*  | *-*a | Ledingham and Pepper (1973) |
| *A. pattersonii* | *Preussiani* James | Spellenberg (1976) |
| *A. pehuenches* | *-*a | Ledingham and Pepper (1973) |
| *A. purshii* | *Argophylli* Gray | Head (1957) |
| *A. quinqueflorus* | *Quinqueflori* Barneby | Spellenberg (1976) |
| *A. racemosus*  | *Bisulcati* Gray | Greene (1969) |
| *A. radicans* | *Strigulosi* Jones | Spellengerg (1976) |
| *A. remotijugus*  | *Caprini* DC. | Farhangisabet *et al*. (2014) |
| *A. riparius* | *Reventi-Arrecti* Jones | Head (1957) |
| *A. rytilobus* | *Onycholobium* Pomel | Rosbakh *et al*. (2020) |
| *A. sabulonum* | *Inflati* Gray | Spellenberg (1976) |
| *A. schizopterus*  | *Proselius* (Stev.) Bunge | Yorgancilar and Erisen (2011) |
| *A. schmolliae*d  | *Lonchocarpi* Gray | Anderson (2004) |
| *A. sclerocarpus* | *Podo-Sclerocarpi* Gray | Head (1957) |
| *A. scopulorum* | *Tiopsidei* Barneby | Spellenberg (1976) |
| *A. serenoi* | *Nudi* Barneby | Spellenberg (1976) |
| *A. sheldonii* | *Reventi-Arrecti* Jones | Head (1957) |
| *A. sieberi*  | *Astragalus* L. | Hammouda and Bakr (1969) |
| *A. siliceous* | *Humillimi* (Jones) Barneby | Spellenberg (1976) |
| *A. spaldingii* | *Chaetodontes* Gray | Head (1957) |
| *A. subsecundus*  | *Laguropsis* Bunge | Zarekia *et al*. (2014) |
| *A. succumbens* | *Malaci* Barneby | Head (1957) |
| *A. sulcatus* | *Megacarpi* (Rydb.) Barneby | Rosbakh *et al*. (2020) |
| *A. tarijensis* | *-*a | Ledingham and Pepper (1973) |
| *A. tegetarioides*  | *Humistrati* (Jones) Barneby | Meinke and Kaye (1992) |
| *A. tephrodes* | *Argophylli* Gray | Spellenberg (1976) |
| *A. tibetanus* | *Glycyrrhizi* Koch | Rosbakh *et al*. (2020) |
| *A. varius* | *Dissitiflori* DC. | Rosbakh *et al*. (2020) |
| *A. vegetus*  | *Onobrychoidei* DC. | Zarekia *et al*. (2014) |
| *A. vesiculosus* | *-*a | Ledingham and Pepper (1973) |

aSouth American species not assigned to sections

 bsyn*. A. glaux*

c syn*. A. propingquus*

d syn *A.* *platycarpus*

**References:**

**Anderson, D.G.** (2004) *Population status survey of Schmoll’s milkvetch
(Astragalus schmolliae C.L. Porter*). Final Report. Colorado Natural Heritage Program, Fort Collins.

**Ashraf, M. and Gohil, R.N.** (1988) Studies on the cytology of legumes of Kashmir Himalaya. I. Cytology of *Astragalus melanostachys* Benth. ex. Bunge with a new base number for the genus. *Caryologia* **41**, 61-67.

**Bowles, M.L., Betz, R.F. and DeMauro, M.M.** (1993) Propagation of rare plants from historic seed collections: implications for species restoration and herbarium management. *Restoration Ecology* **1**, 101-106.

**Castillo, A.M., Márquez. M.H.R., Nieto, C.R.M. and Tristán, J.S.S.** (2003) Germinacion de semillas de hierba loca (*Astragalus mollissimus* Torr.) con diferentes nivelas de humedad y temperature. *Tecnica Pecuaria Mexico* **41**, 85-89.

**Di Martino, L., Di Cecco, V., Di Santo, M., Di Cecco, M., Ciaschetti, G., Marcantonio, G. and Frattaroli, A.R.** (2015) The Majella Seed Bank for the conservation of the endemic, rare or endangered species in Abruzzo: a tangible example of interaction between *ex situ* and *in situ* conservation. *RIBES* series **1**, 49-52.

**Duan, Q.-M., Liang, Z.-S., Mu, Z.-Q. and Wang, W.-L.** (2005) Germination characteristics of *Astragalus membranaceus* seeds. *Xibei Zhiwu Xuebao* **25**, 1246-1249. (in Chinese)

**Erisen, S., Atalay, E. and Yorgancilar, M.** (2011) The effect of thidiazuron on the in vitro shoot development of endemic *Astragalus cariensis* in Turkey. *Turkish Journal Botany* **35**, 521-526.

**Erisen, S., Yorgancilar, M. Atalay, E., Babaoglu, M. and Durna, A. (**2010) Callus induction and plant regeneration of the endemic *Astragalus nezaketae* in Turkey, *Electronic Journal of Biotechnology* **13**, 13-14

**Farhangisabet, A., Majd, A., Nejadsatari, T., Mazooni, A. and Maasomi, A.** (2014) Anatomy and ontogeny of *Astragalus remotijugus* Boiss. & Hohen. seed. *Journal of Plant Development* **21**, 41-47.

**Flüeler, R.P.** (1992) Experimentelle Untersuchungen über Keimung und Etablierung von alpinen Leguminosen. *Verőffentlichungen des Geobotaishcen Institutes der ETH, Stiftung Rübel, Zürich* **110**, 1-149.

**Fotheringham, C.J. and Keeley, J.E.** (1998) *Ecology and distribution of Braunton’s milkvetch (Astragalus brauntonii) and Lyon’s pentachaeta (Penthachaeta lyonii).* California Department of Fish and Game, Region 5, Long Beach, CA.

**Glenn, M.** (2009) *Astragalus lentiginosus var. piscinensis (fish slough milk-vetch). 5-year review: summary and evaluation*. U.S. Fish and Wildlife Service, Ventura, CA.

**Greene, H.C. and Curtis, J.T.** (1950) Germination studies of Wisconsin prairie plants. *The American Midland Naturalist* **43**, 186-194.

**Greene, S.E.** (1969) *Selenium as an essential element for Astragalus species*. Masters thesis. University of Montana, Missoula.

**Hammouda, M.A. and Bakr, Z.Y.** (1969) Some aspects of germination of desert seeds. *Phyton* (Austria) **13**, 183-201

**Head, S.C.** (1957) Mitotic chromosome studies in the genus *Astragalus. Madroño* **13**, 95-106.

**Hotze, B.** (2011) *Astragalus desereticus. Deseret milk-vetch. 5-year review: summary and evaluation*. U.S. Fish and Wildlife Service, West Valley City, UT.

**Hung, C.-Y. and Xie, J.** (2008) Development of an efficient plant regeneration system for the selenium-hyperaccumulator *Astragalus racemosus* and the nonaccumulator *Astragalus canadensis*. *HortScience* **43**, 2138-2142.

**Karron, J.D.** (1989) Breeding systems and levels of inbreeding depression in geographically restricted and widespread species of *Astragalus* (Fabaceae). *American Journal of Botany* **76**, 331-340.

**Kaye, T.N.** (1997) Seed dormancy in high elevation plants: implications for ecology and restoration. pp. 115-120. in Kaye, T.N., Liston, A., Love, R.M., Luoma, D.L., Meinke, R.J. and Wilson, M.V. (eds.), *Conservation and management of native plants and fungi*. Native Plant Society of Oregon, Corvallis, OR.

**Kožuharova, E., Tzvetanova, V. and Firmage, D.** (2010). Seed germination and seedling development of two rare *Astragalus* species (Fabaceae). *Phytologia Balcanica* **16**, 51-56.

**Ledingham, G.F. and Pepper, B.M.** (1973)Chromosome numbers of some South American species of *Astragalus*. *Kurtziana* **7**, 27-37.

**Lorite, J., Ruiz-Girela, M. and Castro, J.** (2007) Patterns of seed germination in Mediterranean mountains: study on 37 endemic or rare species from Sierra Nevada, SE Spain. *Candollea* **62**, 5-16.

**Meinke, R.J. and Kaye, T.N.** (1992) Taxonomic assessment of *Astragalus tegetarioides* (Fabaceae) and a new related species from northern California. *Madroño* **39**, 193-204.

**Melgoza-Castillo, A.** (1995) *Ecology of locoweed (Astragalus mollissimus) in Chihuahua, Mexico*. Ph.D. thesis, New Mexico State University, Las Cruces.

**Merlo, M.E. and Alemán, M.M. (1996)** Efecto de la temperatura sobre la germinacion de especies de *Astragalus* L. y *Genista* L. (Leguminosae). *Monografias de Flora y Vegetation Béticas* **9**, 135-146

**Moghadan, M.K., Haghighi, R.S. and Kelarestaghi, K.B.** (2012) Effect of scarification, GA and chilling on the germination of *Astragalus caragana*[*e*] seeds p. 113. in *Proceedings from National Conference of Natural Production and Medicinal Plants*, September 2012, Bojnourd, Iran.

**Pavlik, B.M. and Barbour, M.G.**  (1988) Demographic monitoring of endemic sand dune plants, Eureka Valley, California. *Biological Conservation* **46**, 217-242.

**Riahi, M. and Zarre, S.** (2009) Seed development in *Astragalus cemerinus* and *A. ruscifolius* (Fabaceae), and its systematic implications. *Acta Biologica Cracoviensia (Series Botanica)* **51**, 7-13.

**Riahi, M., Zarre, S., Chehregani, A. and Shahsavan-Behboudi, B.** (2003) Seed development in two species of medifixed hairy *Astragalus* (Fabaceae). *Flora* **198**, 211-219.

**Ribeiro, K.A.F., Sanchez Agudo, J.A., Sánchez Durán, S., Vega Elices, E. and Sánchez Sánchez, J.** (2019) Attempts to save a Spanish, endemism [endemic] *Astragalus devesae* Talavera, S. González & G. López (Fabaceae) from extinction. *Turkish Journal of Botany* **43**, 116-125.

**Rosbakh, S., Baskin, C.C. and Baskin, J.M.** (2020)Nikolaeva et al.'s reference book on seed dormancy and germination. *Ecology* **101**, e03049. [**https://doi.org/10.1002/ecy.3049**](https://doi.org/10.1002/ecy.3049)

**Rundel, P.W., Huggins, T.S., Prigge, B.A. and Shariff, M.R.** (2012) Community dynamics and soil seed bank ecology of the Lane Mourntain milkvetch (*Astragalus jaegerianus* Munz). Final report to Army Research Office (AMSRD-ARL-RO-EV). US Research Laboratory, Research Triangle Park, NC

**Sankary, M.N. and Barbour, M.G.** (1980) Germination, growth, and water relations of *Astragalus lentiginosus* var. *nigricalycis* (Fabaceae). *Madroño* **27**, 90-96.

**Shi, L.P., Qu, Q.M., Cui, W.J. and Chen, Y.L.** (2014) Study on method and its optimization of improving seed germination of *Astragalus membranaceus* as Gansu traditional medicinal herb. *Zhong Yao Cai* **37**, 548-552. (in Chinese with English abstract)

**Sorensen, J.T. and Holden, D.J.** (1974) Germination of native prairie forb seeds. *Journal of Range Management* **27**, 123-126.

**Spellenberg, R.** (1976) Chromosome numbers and their cytotaxonomic significance for North American *Astragalus* (Fabaceae). *Taxon* **25**, 463-476.

**Townsend, C.E. and McGinnies, W.J.** (1972a) Establishment of nine forage legumes in the Central Great Plains. *Agronomy Journal* **64**, 699-702.

**Townsend, C.E. and McGinnies, W.J.** (1972b) Temperature requirements for seed germination of several forage legumes. *Agronomy Journal* **64**, 809-812.

**Trillo, T.A. and Carro, A.J.M.** (1993a) Variations in seeds of three endemic leguminous species at different altitudes. *Physiologia Plantarum* **87**, 329-334.

**Trillo, T.A. and Carro, A.J.M.** (1993b) Germination, seed-coat structure and protein patterns of seeds from *Adenocarpus decorticans* and *Astragalus granatensis* growing at different altitudes. *Seed Science & Technology* **21**, 317-326.

**Yorgancilar, M. and Erisen, S.** (2011) The effect of thidiazuron (TDZ) on shoot regeneration of *Astragalus schizopterus*. *Journal of Animal and Plant Sciences* **21**, 519-524.

**Zarekia, S., Jafari, A.A. and Esfahan, E.Z.** (2014) Effects of seed scarification on vegetation parameters in some *Astragalus* species under field conditions (case study: Homand Absard, Damavand, Iran). *Journal of Rangeland Science* **4**, 151-158.

**Ziemkiewicz, P.F. and Cronin, E.H.** (1981) Germination of seed of three varieties of spotted locoweed. *Journal of Range Management* **34**, 94-97.