Workshop on:

Developing a hybrid bean collection to advance climate-ready bean breeding


DGD-3381


DGD-3384


DGD-3377

When nature helps your crossing program

Crossed with *P. costaricensis*?


DGD-3373

D.G. Debouck


DGD-3381

Cali@Cambridge, 1 March 2022

New germplasm of *Phaseolus dumosus* from Panama: Debouck & Rodríguez-Quiel 2020

Bean breeding

The purpose: to combine into a productive variety the traits that meet the needs of the farmer and the consumer, and reduce production costs and environmental footprint at the original location.

The question: can we shorten the process?

sources: Chacón-Sánchez et al. 2005, 2012; Kaplan & Lynch 1999; Kwak et al. 2009; Mamidi et al. 2011
Garvin & Weeden 1994; Schmit & Debouck 1991

The bean genus: what do we have? 81 species to date in two clades

clade A has no cultivated species; 8 sections, 42 species; *Minkelersia* being the largest

- sect. *Minkelersia* — 10 sp.
- sect. *Pedicellati* — 9 sp.
- sect. *Brevilegumeni* — 6 sp.
- sect. *Xanthotricha* — 6 sp.
- sect. *Digitati* — 5 sp.
- sect. *Bracteati* — 2 sp.
- sect. *Chiapasana* — 1 sp.
- sect. *Revoluti* — 1 sp.

clade B has all cultivated species; 6 sections, 39 species; *Paniculati* being the largest

- sect. *Paniculati* — 20 sp. — Lima bean
- sect. *Coriacei* — 4 sp.
- sect. *Falcati* — 3 sp.
- sect. *Rugosi* — 3 sp.
- sect. *Acutifolii* — 2 sp. — tepary bean, *montanus*
- sect. *Phaseoli* — 7 sp. — common bean, year bean, scarlet runner

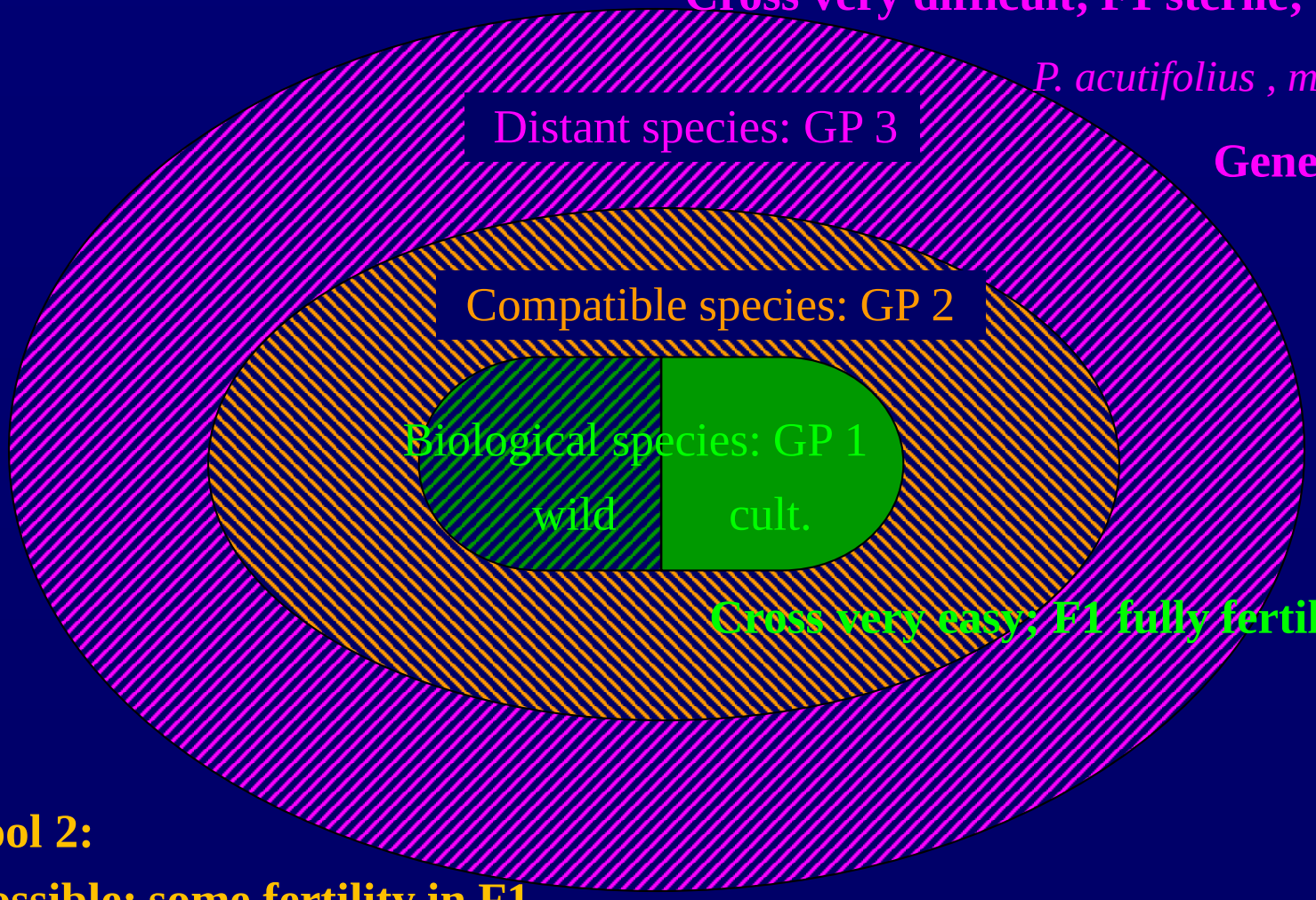
sources: Debouck 2021, Delgado-Salinas et al. 2006, Freytag & Debouck 2002, Porch et al. 2013

Gene pools of common bean

Cross very difficult; F1 sterile; *in vitro*

P. acutifolius , montanus

Gene Pool 3



Cross very easy; F1 fully fertile

Gene Pool 2:

Cross possible; some fertility in F1

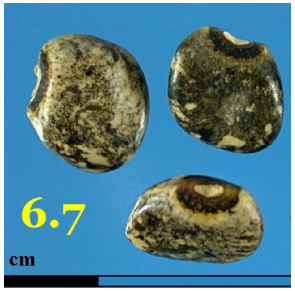
P. albescens, coccineus, costaricensis, debouckii, dumosus, persistentus

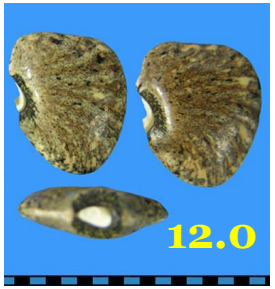
adapted from: Debouck 1999, Harlan & de Wet 1971

Bean species are ‘good’ species and natural hybrids are rare! but . . .

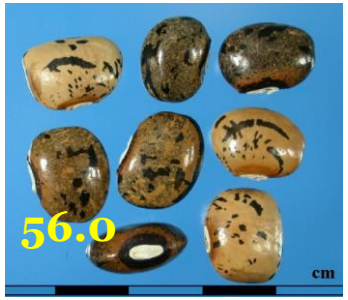
acutifolius *coccineus* *dumosus* *lunatus* *vulgaris*

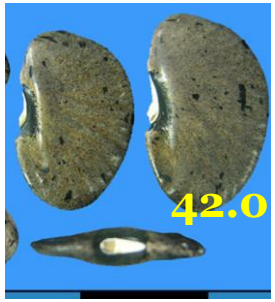
wild types:



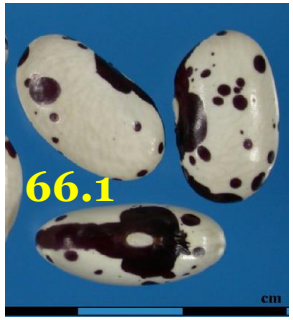


weedy types:



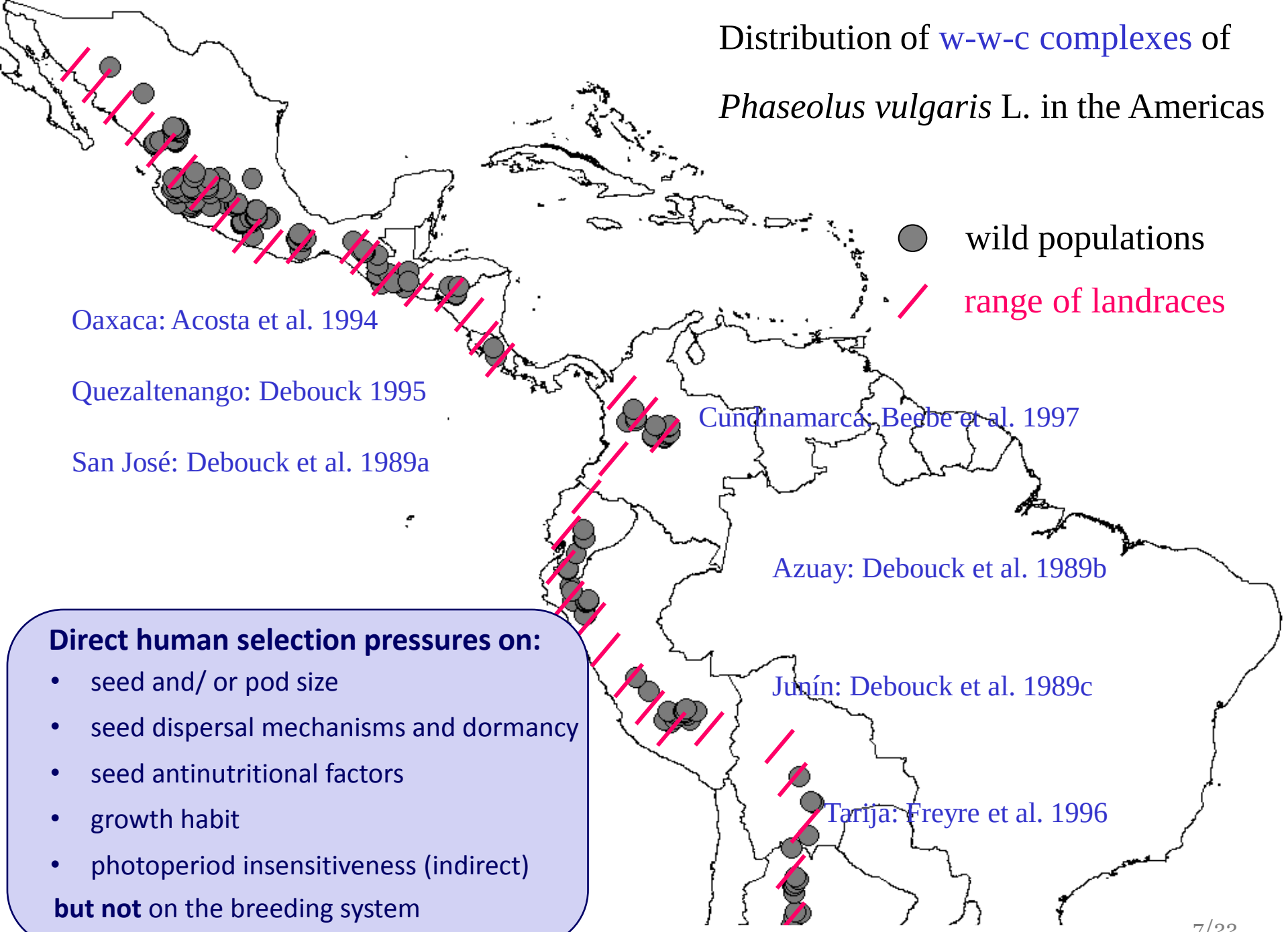


cultivated types:



source: CIAT genebank 2022

Distribution of w-w-c complexes of *Phaseolus vulgaris* L. in the Americas



Direct human selection pressures on:

- seed and/ or pod size
- seed dispersal mechanisms and dormancy
- seed antinutritional factors
- growth habit
- photoperiod insensitiveness (indirect)

but not on the breeding system

sources: Escalante et al. 1994, Gepts & Debouck 1991

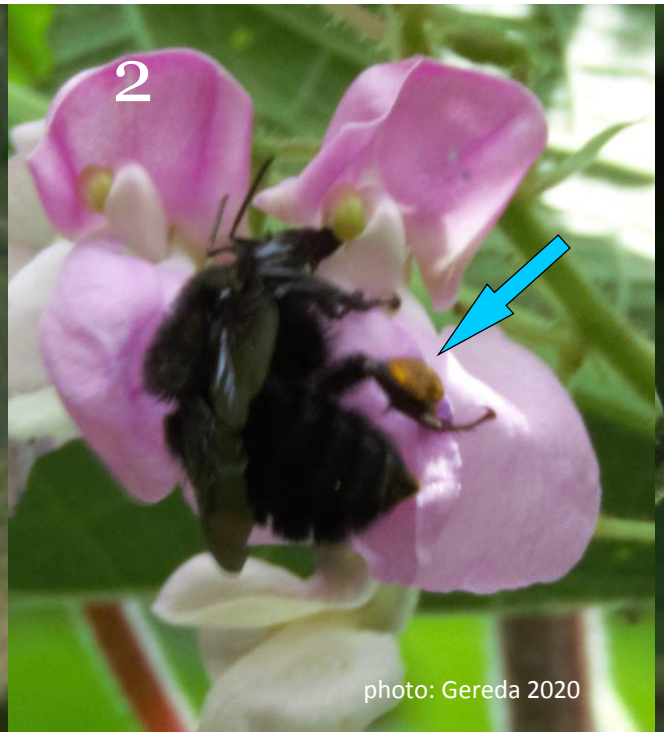
Traits of interest for common bean breeding

Donor species	trait	source
P. coccineus 	anthracnose	Mahuku et al. 2002
	ascochyta blight	Schmit & Baudoin 1992
	Fusarium root rot	Wallace & Wilkinson 1965
	virus BGYMV	Osorno et al. 2007
	white mold	Abawi et al. 1978
	aluminum toxicity	Butare et al. 2011
	low temperatures seedling	Rodiño et al. 2007
P. dumosus 	angular leaf spot	Mahuku et al. 2003
	anthracnose	Hubbeling 1957
		Mahuku et al. 2002
	ascochyta blight	Schmit & Baudoin 1992
		Hanson et al. 1993
	bean fly	Schmit & Baudoin 1987
	white mold	Hunter et al. 1982
	high iron in seeds	Beebe 2012

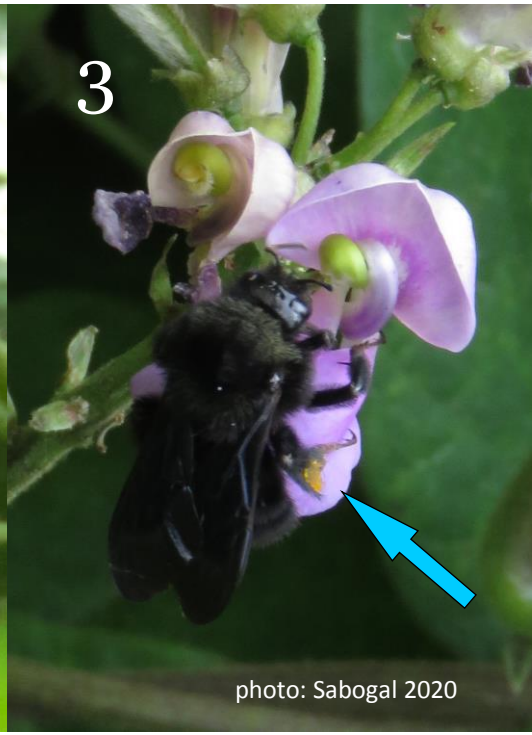
What are these bees doing? Well, feeding themselves from the nectar of bean flowers.

P. vulgaris in Popayán

P. dumosus in Tenerife



P. tuerckheimii in Tenerife

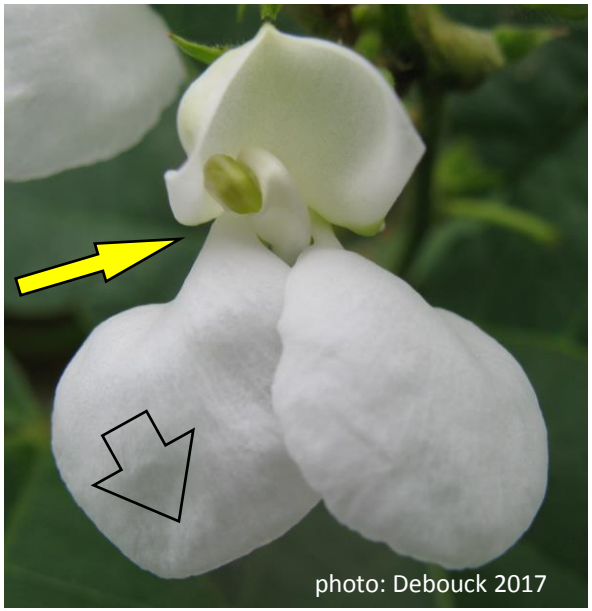


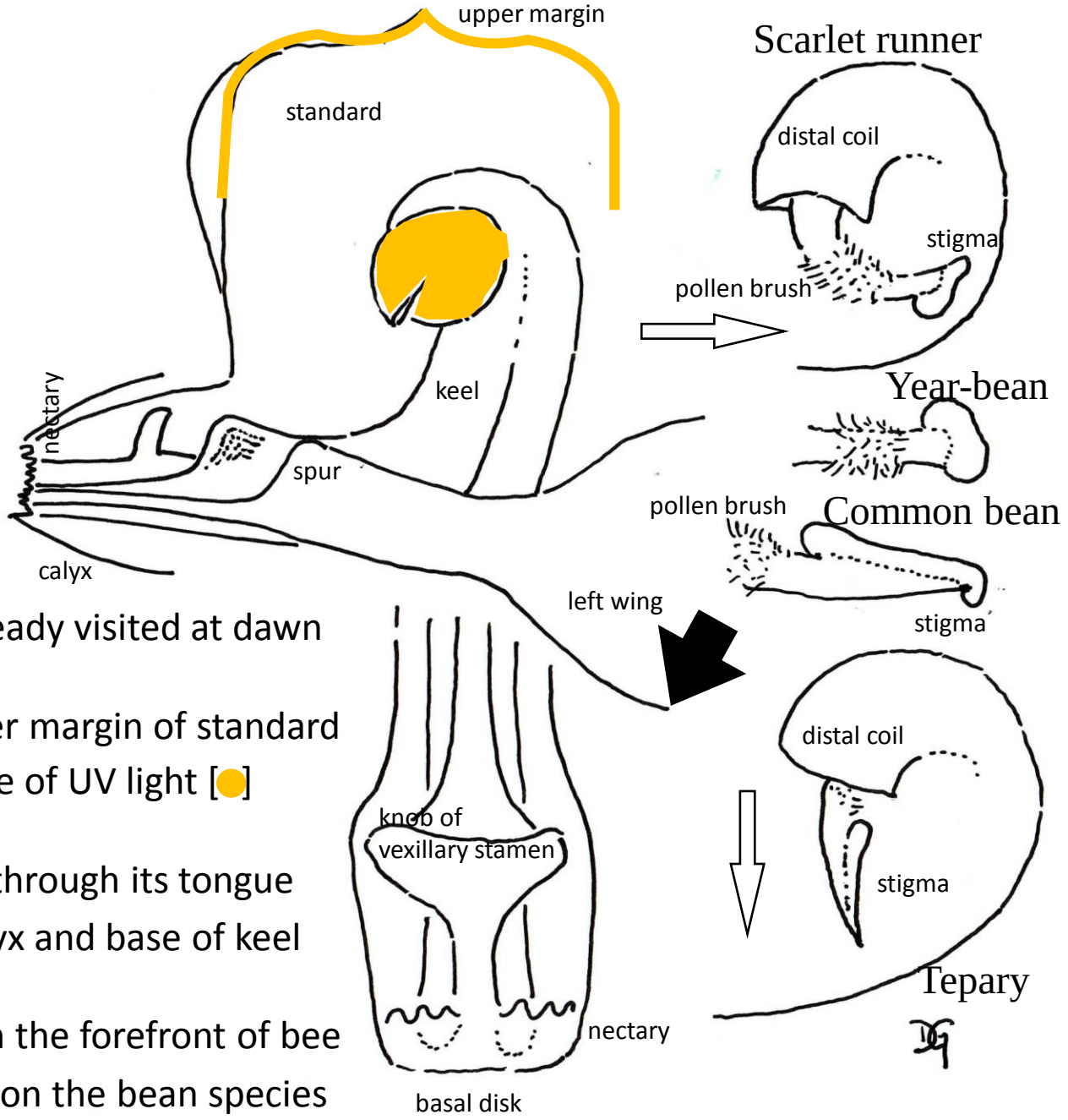
1. Probably getting nectar, although carpenter bee is oversized in relation to the flower

2. Having trouble to obtain nectar, because the bee is too light; sure will not get pollen

3. Probably will get nectar and collect pollen too on its forefront

sources: Chacón-Sánchez et al. 2021, Kendall & Smith 1976, Koltowski 2004





- flower of *P. dumosus* already visited at dawn
- last coil of keel and upper margin of standard with different reflectance of UV light [●]
- the bee gets the nectar through its tongue introduced between calyx and base of keel
- pollen from the brush on the forefront of bee variable load depending on the bean species

sources and additional reading: Chacón-Sánchez et al. 2021, Darwin 1858, Lavin & Delgado-Salinas 1990 , Sousa-Peña et al. 1996

The *dumosus* case (1)

P. coccineus, 'Patol Blanco', Zacatecas, 1978

P. dumosus, 'Cacha Blanco', Putumayo, 1985

- often planted together
- in the range 1,800-2,600 masl
- under more than 2,000 mm/ year
- in Veracruz, Puebla, Oaxaca, Chiapas in Mexico
- in San Marcos, Quezaltenango Alta Verapaz in Guatemala

sources: CIAT genebank 2022, Debouck 1992, Hernández-Xolocotzi et al. 1959, Schmit & Debouck 1991

The *dumosus* case (2)

P. coccineus L.

P. dumosus Macfadyen

What the traditional (Amerindian) farmers considered:			
Human group	location	*P. coccineus*	*P. dumosus*
Totonaco	NW Puebla, Mexico	shaushana	xuyumel
Nahuatl	N Puebla, Mex.	ayocote	acaletl
Zapotec	S Oaxaca, Mex.	tashena	tabay
Tzotzil	C Chiapas, Mex.	botíl	ibes
Mam	Sn Marcos, Guatemala	chomborote	dzich
Kaqchikel	Chimaltenango, Guat.	piloy	piloya
Quichíl	Alta Verapaz, Guat.	piloy	piligüe

sources: CIAT genebank 2022, Coe et al. 1986, Debouck 1992, Delgado-Salinas 1988

- hypogeal germination
- tuberous roots
- extrorse stigma
- hilum oval

- epigeal germination
- thickened fibrous roots
- apical stigma
- orbicular hilum

sources: Freytag 1965, Delgado-Salinas 1988, Freytag & Debouck 2002

The *dumosus* case (3)

What is the origin of that bean crop?

1959: Hernández-X. et al.: a natural hybrid of cultivated *P. coccineus* (cytoplasm donor) with cultivated *P. vulgaris* (pollen donor) because of interbreeding of both crops

1967: Miranda-Colín: the natural hybrid was backcrossed with *P. coccineus* (pollen donor)

1982: Shii et al.: the artificial hybrid *cocc x vulg* was obtained by embryo culture

1978: Freytag and Vakili found in Sololá a wild bean close to the subsp. *darwinianus* of Hdz-X.

1985-90: Debouck and co-workers found more populations of that wild bean in SW Guatemala

1991: the differences between wild and cultivated *dumosus* are related to domestication

1993: Schmit et al. showed that *dumosus* belongs to the *vulgaris* phylum on cpDNA evidence

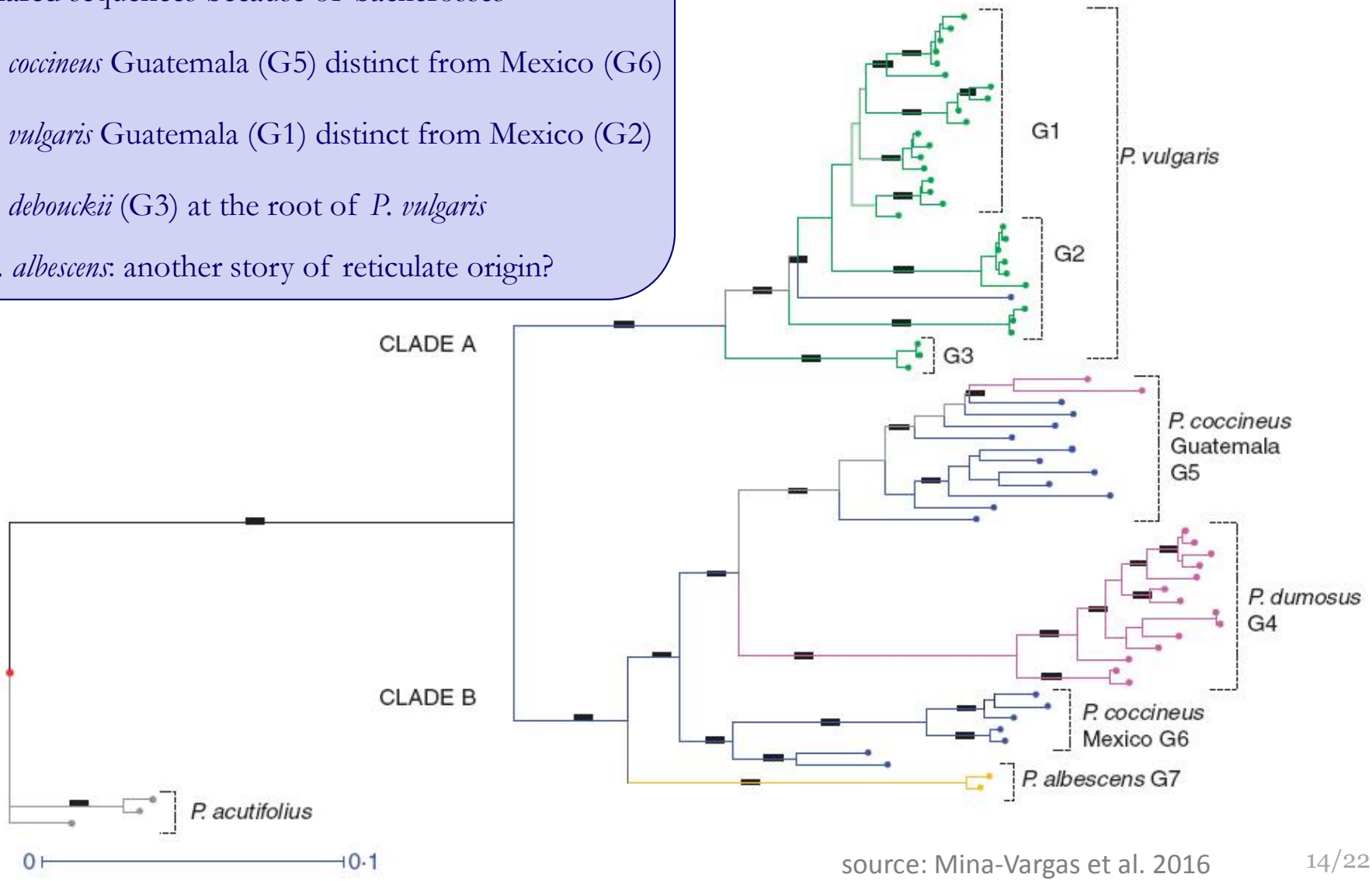
1994: Llaca et al. also noted the many *coccineus* sequences in the nuclear genome of *dumosus*

2000: Gepts et al. estimated the divergence of *vulgaris* from *coccineus* and *dumosus* at 2 x 10^6 years

2016: Mina-Vargas et al. showed a reticulate origin of *dumosus* from hybridization of *vulg* x *cocc*, followed by at least two hybridizations with *cocc* of Guatemala; low diversity in it

Neighbor-joining dendrogram of polymorphisms in 4,208 DArT markers of genomic DNA

- *P. dumosus* (G4) close to *cocc* (G5) (pollen donor) shared sequences because of backcrosses
- *P. coccineus* Guatemala (G5) distinct from Mexico (G6)
- *P. vulgaris* Guatemala (G1) distinct from Mexico (G2)
- *P. debouckii* (G3) at the root of *P. vulgaris*
- *P. albescens*: another story of reticulate origin?



source: Mina-Vargas et al. 2016

DGD-3314

Phaseolus x *costaricensis dumosus*, det. D.G. Debouck, 28/XI/2016. COSTA RICA, **San José**, León Cortés, distrito de San Andrés, 4 km W de intersección de ruta 226 hacia San Francisco. GPS: Lat. 09º 42’ 16.3”N. Long. 84º 04’ 57.5”W. Alt. 2,121 msnm. Fecha de recolección: 28/XI/2016.

photos: Debouck 1985

Final remarks

- *Phaseolus* has a breeding system of autogamy and auto-compatibility
- to survive in the wild an association with insects Hymenoptera was selected
- at this time of evolution, the association seems very active in the *Phaseoli*
- the stability of *dumosus* is puzzling, while other hybrids are generated
- once stabilized *dumosus* has colonized new humid forest habitats
- *P. dumosus* was domesticated for that ecological capacity, little found elsewhere
- for that same capacity humans distributed it in the Caribbean and the Andes

The early separations in the *Phaseoli*

The ancient hybrid taxa

The hybridizations under way

What's next in the *Phaseoli* ?

vulgaris albescens vulg x cocc

debouckii costaricensis costa x dumos

coccineus dumosus cocc x dumos

sources and additional reading: Chacón-Sánchez et al. 2021, Ellstrand & Schierenbeck 2000, Weinstein 1926

photos: Debouck, various dates

References (1)

Abawi, G.S., R. Provvidenti, D.C. Crosier & J.E. Hunter. 1978. Inheritance of resistance to white mold disease in *Phaseolus coccineus*. J. Hered. 69 (3): 200-202.

Acosta-Gallegos, J.A., P. Gepts & D.G. Debouck. 1994. Observations on wild and weedy forms of common bean in Oaxaca, Mexico. Annu. Rep. Bean Improvement Coop. (USA) 37: 137-138.

Beebe, S.E. 2012. Common bean breeding in the tropics. Plant Breeding Reviews 36: 357-426.

Beebe, S.E., O. Toro-Chica, A.V. González, M.I. Chacón-Sánchez & D.G. Debouck. 1997. Wild-weed-crop complexes of common bean (*Phaseolus vulgaris* L., Fabaceae) in the Andes of Peru and Colombia, and their implications for conservation and breeding. Genet. Resources & Crop Evol. 44 (1): 73-91.

Butare, L., I. Rao, P. Lepoivre, J. Polania, C. Cajiao, J. Cuasquer & S. Beebe. 2011. New genetic sources of resistance in the genus *Phaseolus* to individual and combined aluminium toxicity and progresive soil drying stresses. Euphytica 181 (3): 385-404.

Chacón-Sánchez, M.I., J. Martínez-Castillo, J. Duitama & D.G. Debouck. 2021. Gene flow in *Phaseolus* beans and its role as a plausible driver of ecological fitness and expansion of cultigens. Front. Ecol. Evol. 9 (618709): 1-25.

Chacón-Sánchez, M.I., J.R. Motta-Aldana, M.L. Serrano-Serrano & D.G. Debouck. 2012. Domestication of Lima beans: a new look at an old problem. *in*: "Biodiversity in agriculture: domestication, evolution, and sustainability", P. Gepts, T.R. Famula, R.L. Bettinger, S.B. Brush, A.B. Damania, P.E. McGuire & C.O. Qualset (eds.), Cambridge University Press, Cambridge, United Kingdom. Pp. 330-343.

Chacón-Sánchez, M.I., B. Pickersgill & D.G. Debouck. 2005. Domestication patterns in common bean (*Phaseolus vulgaris* L.) and the origin of the Mesoamerican and Andean cultivated races. Theor. Appl. Genet. 110 (3): 432-444.

CIAT Genebank. 2022. Passport data of accessions of *Phaseolus* beans. https://ciat.cgiar.org/what-we-do/crop-conservation-and-use/ files. Accessed on 20 February 2022.

Coe, M., D. Snow & E. Benson. 1986. Atlas of Ancient America. Equinox Books. Oxford, England. 240p.

Darwin, C. 1858. On the agency of bees on the fertilization of papilionaceous flowers and on the crossing of kidney beans. Ann. Mag. Nat. Hist. 2: 459-465.

Debouck, D.G. 1992. Frijoles, *Phaseolus* spp. *in*: "Cultivos marginados: otra perspectiva de 1492", E. Hernández Bermejo & J. León (eds). Food and Agriculture Organization of the United Nations, Rome, Italy. Pp. 45-60.

Debouck, D.G. 1995. Germplasm exploration for the genera Manihot and Phaseolus in western and central Guatemala. International Plant Genetic Resources Institute, Rome, Italy. Mimeographed. 31p.

Debouck, D.G. 1999. Diversity in *Phaseolus* species in relation to the common bean. *in*: "Common bean improvement in the twenty first century", S.P. Singh (ed.), Kluwer Academic Publishers, Dordrecht, The Netherlands. Pp. 25-52.

References (2)

Debouck, D.G. 2021. *Phaseolus* beans (Leguminosae, Phaseoleae): a checklist and notes on their taxonomy and ecology. J. Bot. Res. Inst. Texas 15 (1): 73-111.

Debouck, D.G., R. Araya-Villalobos, R.A. Ocampo-Sánchez & W.G. González-Ugalde 1989a. Collecting *Phaseolus* in Costa Rica. FAO/IBPGR Plant Genet. Resources Newsl. 78/79: 44-46.

Debouck, D.G., R. Castillo T. & J.M. Tohme. 1989b. Observations on little-known *Phaseolus* germplasm of Ecuador. FAO/IBPGR Plant Genet. Resources Newsl. 80: 15-21.

Debouck, D.G., M. Gamarra-Flores, V. Ortiz-Arriola & J. Tohme. 1989. Presence of a wild-weed-crop complex in *Phaseolus vulgaris* L. in Peru? Annu. Rept Bean Improvement Coop. (USA) 32: 64-65.

Debouck, D.G. & E. Rodríguez-Quiel. 2020. Avances sobre los recursos genéticos de fríjol (*Phaseolus* sp.) en Panamá. Ciencia Agropecuaria 30: 66-85.

Delgado-Salinas, A. 1988. Variation, taxonomy, domestication, and germplasm potentialities in *Phaseolus coccineus*. *in*: "Genetic resources of *Phaseolus* beans", P. Gepts (ed.). Kluwer Academic Publishers. Dordrecht, Holland. Pp. 441-463.

Delgado-Salinas, A., R. Bibler & M. Lavin. 2006. Phylogeny of the genus *Phaseolus* (Leguminosae): a recent diversification in an ancient landscape. Syst. Bot. 31 (4): 779-791.

Ellstrand, N.C. & K.A. Schierenbeck. 2000. Hybridization as a stimulus for the evolution of invasiveness in plants. Proc. Natl. Acad. Sci. USA 97 (13): 7043-7050.

Escalante, A.M., G. Coello, L.E. Eguiarte & D. Piñero. 1994. Genetic structure and mating systems in wild and cultivated populations of *Phaseolus coccineus* and *P. vulgaris* (Fabaceae). Amer. J. Bot. 81 (9): 1096-1103.

Freyre, R., R. Ríos, L. Guzmán, D.G. Debouck & P. Gepts. 1996. Ecogeographic distribution of *Phaseolus* spp. (Fabaceae) in Bolivia. Econ. Bot. 50 (2): 195-215.

Freytag, G.F. 1965. Clasificación del fríjol común (*Phaseolus vulgaris* L. y especies afines). Ceiba 11 (1): 51-64.

Freytag, G.F. & D.G. Debouck. 2002. Taxonomy, distribution, and ecology of the genus *Phaseolus* (Leguminosae-Papilionoideae) in North America, Mexico and Central America. SIDA Bot. Misc. 23: 1-300.

Garvin, D.F. & N.F. Weeden. 1994. Isozyme evidence supporting a single geographic origin for domesticated tepary bean. Crop Sci. 34 (5): 1390-1395.

Gepts, P. & D.G. Debouck. 1991. Origin, domestication, and evolution of the common bean (*Phaseolus vulgaris* L.). *in*: "Common beans: research for crop improvement", A. van Schoonhoven and O. Voysest (eds.), Commonwealth Agricultural Bureaux International, Wallingford, United Kingdom. Pp. 7-53.

References (3)

Gepts, P., R. Papa, S. Coulibaly, A. González-Mejía & R. Pasquet. 2000. Wild legume diversity and domestication - Insights from molecular methods. *in*: "Wild legumes", K. Oono (ed.). Ministry of Agriculture, Forestry and Fisheries, and National Institute of Agrobiological Resources. Tsukuba, Ibaraki, Japan. Pp. 19-31.

Hanson, P.M., M.A. Pastor-Corrales & J.L. Kornegay. 1993. Heritability and sources of *Ascochyta* blight resistance in common bean. Plant Disease 77 (7): 711-714.

Harlan, J.R. & J.M.J. de Wet. 1971. Toward a rational classification of cultivated plants. Taxon 20(4): 509-517.

Hernández-Xolocotzi, E., S. Miranda-Colín & C. Prywer. 1959. El origen de *Phaseolus coccineus* L. *darwinianus* Hdz. & Miranda C., *subspecies nova*. Rev. Soc. Mex. Hist. Nat. 20 (1-4): 99-121.

Hubbeling, N. 1957. New aspects of breeding for disease resistance in beans (*Phaseolus vulgaris* L.). Euphytica 6 (2): 111-141.

Hunter, J.E., M.H. Dickson, M.A. Boettger & J.A. Cigna. 1982. Evaluation of plant introductions of *Phaseolus* spp. for resistance to white mold. Plant Dis. 66 (4): 320-322.

Kaplan, L., & T. Lynch. 1999. *Phaseolus* (Fabaceae) in archaeology: AMS radiocarbon dates and their significance for pre-Colombian agriculture. Econ. Bot. 53 (3): 261-272.

Kendall, D.A. & B.D. Smith. 1976. The pollinating efficiency of honeybee and bumblebee visits to flowers of the runner bean *Phaseolus coccineus* L. J. Appl. Ecol. 13 (3): 749-752.

Koltowski, Z. 2004. Flowering biology, nectar secretion and insect foraging of the runner bean (*Phaseolus coccineus* L.). Journal of Apicultural Science 48 (2): 53-60.

Kwak, M., J.A. Kami & P. Gepts. 2009. The putative Mesoamerican domestication center of *Phaseolus vulgaris* is located in the Lerma-Santiago basin of Mexico. Crop Sci. 49 (2): 554-563.

Lavin, M. & A. Delgado-Salinas. 1990. Pollen brush of Papilionoideae (Leguminosae): morphological variation and systematic utility. Amer. J. Bot. 77 (10): 1294-1312.

Llaca, V., A. Delgado-Salinas & P. Gepts. 1994. Chloroplast DNA as an evolutionary marker in the *Phaseolus vulgaris* complex. Theor. Appl. Genet. 88 (6-7): 646-652.

Mahuku, G.S., C. Jara, C. Cajiao & S. Beebe. 2002. Sources of resistance to *Colletotrichum lindemuthianum* in the secondary gene pool of *Phaseolus vulgaris* and in crosses of primary and secondary gene pools. Plant Disease 86 (12): 1383-1387.

Mahuku, G.S., C. Jara, C. Cajiao & S. Beebe. 2003. Sources of resistance to angular leaf spot (*Phaeoisariopsis griseola*) in common bean core collection, wild *Phaseolus vulgaris* and secondary gene pool. Euphytica 130 (3): 303-313.

Mamidi, S., M. Rossi, D. Annam, S. Moghaddam, R. Lee, R. Papa & P. McClean. 2011. Investigation of the domestication of common bean (*Phaseolus vulgaris*) using multilocus sequence data. Functional Plant Biol. 38 (12): 953-967.

References (4)

Mina-Vargas, A.M., P.C. McKeown, N.S. Flanagan, D.G. Debouck, A. Kilian, T.R. Hodkinson & C. Spillane. 2016. Origin of year-long bean (*Phaseolus dumosus* Macfady., Fabaceae) from reticulated hybridization events between multiple *Phaseolus* species. Ann. Bot. 118 (5): 957-969.

Miranda-Colín. 1967. Infiltración genética entre *Phaseolus coccineus* L. y *Phaseolus vulgaris* L. Colegio de Postgraduados, Escuela Nacional de Agricultura. Chapingo, Mexico. Serie de Investigación no. 9. 49p.

Osorno, J.M., C.G. Muñoz, J.S. Beaver, F.H. Ferwerda, M.J. Bassett, P.N. Miklas, T. Olczyk & B. Bussey. 2007. Two genes from *Phaseolus coccineus* confer resistance to Bean Golden Yellow Mosaic Virus in common bean. J. Amer. Soc. Hort. Sci. 132 (4): 530-533.

Porch, T.G., J.S. Beaver, D.G. Debouck, S. Jackson, J.D. Kelly & H. Dempewolf. 2013. Use of wild relatives and closely related species to adapt common bean to climate change. Agronomy 3: 433-461.

Rodiño, A.P., M. Lema, M. Pérez-Barbeito, M. Santalla & A. de Ron. 2007. Assessment of runner bean (*Phaseolus coccineus* L.) germplasm for tolerance to low temperature during early seedling growth. Euphytica 155 (1-2): 63-70.

Schmit, V. & J.P. Baudoin. 1987. Multiplication et évaluation de *Phaseolus coccineus* L. et *Phaseolus polyanthus* Greenm., deux espèces intéressantes pour l'amélioration de la productivité des légumineuses vivrières. Bull. Rech. Agron. Gembloux 22 (3): 235-253.

Schmit, V. & J.P. Baudoin. 1992. Screening for resistance to *Ascochyta* blight in populations of *Phaseolus coccineus* L. and *P. polyanthus* Greenman. Field Crops Res. 30 (1-2): 155-165.

Schmit, V. & D.G. Debouck. 1991. Observations on the origin of *Phaseolus polyanthus* Greenman. Econ. Bot. 45 (3): 345-364.

Schmit, V., P. du Jardin, J-P. Baudoin & D.G. Debouck. 1993. Use of chloroplast DNA polymorphisms for the phylogenetic study of seven *Phaseolus* taxa including *P. vulgaris* and *P. coccineus*. Theor. Appl. Genet. 87 (4): 506-516.

Shii, C.T., A. Rabakoarihanta, M.C. Mok & D.W.S. Mok. 1982. Embryo development in reciprocal crosses of *Phaseolus vulgaris* L. and *P. coccineus* Lam. Theor. Appl. Genet. 62 (1): 59-64.

Sousa-Peña, M., A. Wong-León & A. Delgado-Salinas. 1996. Pollination dynamics and evolution in the *Phaseolus coccineus* L. complex. *in*: "Advances in legume systematic. 8. Legumes of economic importance", B. Pickersgill & J.M. Lock (eds.), Royal Botanic Garden, Kew, UK. Pp. 75-81.

Wallace, D.H. & R.E. Wilkinson. 1965. Breeding for *Fusarium* root rot resistance in beans. Phytopathology 55 (11): 1227-1231.

Weinstein, A.I. 1926. Cytological studies on *Phaseolus vulgaris*. Amer. J. Bot. 13 (4): 248-263.

Many thanks for your attention!

and a big 'Thank you' to:

in the lab	in the countries	for the support
Ana L Caicedo	Jorge Acosta	AGCD
Maria I Chacón	Rodolfo Araya	BMZ
Jorge Duitama	César Azurdia	CENTA
Eliana Gaitán	Raúl Castillo	CIAT
Rosa González	Néstor Chaves	CIFP
Alberto Gutiérrez	Hipólito de la Cruz	COSUDE
Antonio Hernández	George Freytag+	EU
Jorge Hernández	Paul Gepts	DfID
Celia Lima	Rogelio Lépiz	GCDT
Jenny Motta	Luís López	Gov Norway
Martha Serrano	Jorge Liñan	IBPGR
Alba M Torres	José Muruaga	ICA
Joe Tohme	Raúl Ríos	ICTA
Orlando Toro+	María C Sevillano	IDIAP
	Luís Valera	INIA
		INIAP
		INIFAP
		INTA
		IUCN
		UCR
		USAID
		USCG
		USDA
		World Bank