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Contribution of the Argentine Germplasm to the Improvement of Sunflower

Abstract: The sunflower breeding carried out in Argentina constitutes a valuable contribution to the spreading of the crop both locally and internationally. Exchange among breeders at international level makes it possible to achieve objectives that would be restricted if only local germplasm were available (lack of variability). The National Institute of Agricultural Technology (INTA) has had a sunflower genetic breeding program at Pergamino Experimental Station (EEA) since 1939 and another program at Manfredi Experimental Station (EEA) since 1950 with the overall goal of contributing to increase the rate of genetic progress of the crop. At first the program development open pollination varieties using the populations which were introduced both by immigrants adapted to local conditions and by intercrossing them. With the development of cytoplasmic androsterility in the 1970s, the programs focused on producing inbred lines to develop hybrids. The varieties and lines were made available to other breeders in a scheme of exchange that allowed INTA, other national breeders and breeders from other countries to obtain new materials. In this way it became clear the great wealth of INTA germplasm for resistance to major crop diseases such as Verticillium wilt, rust and downy mildew. Other important traits improved were the increase of seed weight and tolerance to bird damage by adding striated seeds and decumbent heads. Also by its origin INTA germplasm enabled the increase of oil content, improvements in the quality and specialties (high oleic acid, confectionery) and tolerance to herbicides (imidazolinone), while maintaining the performance and health of the materials. This paper describes the origins and characteristics of INTA lines and also their use in other breeding programs for the creation of new cultivars.

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Introduction

The National Institute of Agricultural Technology (INTA) has led a sunflower genetic improvement program at Pergamino Experimental Station (EEA) since 1939 and at Manfredi Experimental Station (EEA) since 1950 with the overall goal of contributing to increase the rate of genetic progress of the species.

The initial objective of the program was to develop open pollination varieties using the populations introduced both by immigrants adapted to local conditions and by intercrossing them (de Romano and Vazquez, 2003).

With the development of cytoplasmic androsterility in the 1970s, the program focused on producing inbred lines at Pergamino Experimental Station (EEA) (González and Mancuso, 2004; González et al. 2011) and developing hybrids at Manfredi Experimental Station (EEA). Since 2006, both programs have complemented each other to expand their activities, currently reaching evaluation in the pre-commercial phase of co-hybrids of shared germplasm, streamlining the use of the genetic variability of the crop.

The flow of germplasm among breeders of the public and private sectors enables the expansion of the genetic base of breeding programs with the aim of forming populations, so as to obtain cultivars with outstanding attributes (disease resistance, high content of oleic acid, tolerance to herbicides, etc.). Since the 1990s, there has been a significant change because of the appearance of striated hybrids developed by local improvement programs, which resulted in a significant increase in yields and plant health.

This exchange at international level makes it possible to achieve objectives that would be restricted if only local germplasm was available (lack of variability).

The objective of this work is to inform about the origin and characteristics of the lines obtained by INTA and also of its use in other improvement centers for the creation of new cultivars.

Results

Part I: Lines made in INTA with different improved characters[1]

Resistance to diseases

Resistance to *Verticillium dahliae* (Kleb.)
Verticillium resistance was originated from VNIIMK 1646; VNIIMK 1646/ND 01; SB/BZ BXC/KLM, BXC/KLM/HA 300, E/DXT; Local/Silvestre; Puntano/Smena; P4 and HA 335/HA 412/ND 01/BZ.

Resistance to Downy mildew (*Plasmopara halstedii* (Farlow) Berlese & de Toni)
Downy mildew resistance was originated from HA 335/HA412; C.Rf Yugoslavia/Manfredi; HA 335/SelPuntanoXSmena//Impira; C.Rf Australia/Manfredi; E.75x MP 557/Negro Bellocq/KLM/HA 300; HA 335/HA412/71/538/BXC; MP 557/Negro Bellocq/KLM/HA 300/V112/E/BXC; HA 335/Loc. SelPered. B83-3; HA 335/Loc. Sel Comangir(B06)//Impira Sel 427(B03) and HA 335/Loc. Sel Guayacán(B17)//C Ruso/Manfredi(B59).

From HA 335/HA412 and MP 557/Negro Bellocq/KLM/HA 300/V112/E/BXC were also obtained lines that were moderately resistant to Verticillium.

Resistance to *Sclerotinia sclerotiorum* (Lib. de Bary)
Sclerotinia resistance was originated from A83-3/RG-98-657-3; MP 557/Negro Bellocq/HA 89; ND 01; PGRK, V-13/BxC; AXB/BXC; SelB2, Comp. B USA; Ella, Sel-1 and A83-3/C811-15/C829.

From ND 01 and A83-3/RG-98-657-3 were originated also high oleic lines and from AXB/BXC moderately Verticillium resistant lines.

Resistance to rust (*Puccinia helianthi* (Schw.))
Resistance to rust was obtained from Poman-Sel91-13; BXC; Pehuén/Caburé//Charata-SelRN160 and Puntano/Smena Sel.81-45.

Resistance to virus diseases (SuMCoV)

Resistance to virus diseases (SuMCoV) was originated from PuntanoxSmena B09/silvestre Argentino S10d.

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High content of oleic acid

High content of oleic acid lines were obtained from ND 01; VNNIMK 1646/ND 01; Guayacán-Sel.B76-2/C.B Alto Oleico 92; Sel HA 343; Luch…/AO 01/03; ND 01/BXC; B83-3/HA342; A83-3/RG-98-659-4 and Sel C. R Alto Oleico 92. From Luch…/AO 01/03 and VNNIMK 1646/ND 01 were originated also moderately Verticillium resistant lines and from ND 01 Sclerotinia resistant lines.

Resistance to Imidazolinone

Imidazolinone resistant lines were obtained from IMI-Sun North Dakota; B10//B83/HA425 and A83-3/RfI.

From Sel.2329 IMI-Sun North Dakota and Sel.2330 IMI-Sun North Dakota were originated Verticillium resistant lines.

Tolerance to water stress

Tolerance to water stress was originated from B83-3/HA335 and HA89/RHA274/91T608//R049.

Resistance to birds (striated achene and decumbent head)

Resistance to birds was originated from PGRK and sintética Os2.

Long cycle

Long cycle lines were obtained from PGRK; Puntano, A83-4/R79-25-1522-2 and A83-3/RHA361.

Short cycle

Short cycle lines were obtained from P1; Sintética O S2, Mezcla Percoz (ruso × silvestre); Peredovik, Peredovick/Cernianka)//(Cordobés/Impira), C. Rf USA_Sel SB254; A83-3/C.Rf AUSTRALIA-HS101 Sel R79-13-232-1; C. Rf USA- Sel R88-189-5 and A83-3/C. Rf USA.

Use for bird consumption

The line for bird consumption with white achene was obtained from the selection of the NSP Yugoslav population.

Confectionery use

Confectionery lines were obtained from B101/BNDNOB5 Sel-1; B101/USA BHA351; B101/BNDNOM3; A101/C. Rf G99-661-3 and A101/C. Rf G99-662-4.

According to Tables 1 and 2 and Figures 1 and 2, eleven lines were obtained that were resistant to Verticillium and fourteen lines resistant to Downy mildew,

Table 1: Lines developed at INTA Pergamino with different improved characters.

Line	Origin	Character
AO 01/04	ND-01-1397-3-1-3-4	High oleic (86.7% oleic), MR to Sclerotinia
AO 02/01	2872-1-6 (HA 343 × Hib.F1 nº 2))	High oleic (90.4% oleic)
AO 03/13	ND-01-1397-3-4-3-6	High oleic (88,03% oleic)
AO 03/15	ND-01-1397-3-3-2	High oleic (92,04% oleic)
AO 03/17	2841-3-5-3 (HA 343 × Hib.F1 nº 1)	High oleic (90.6% oleic)
AO-01/01	ND-01-1394-1-1-1	High oleic (85.4% oleic), R to Sclerotinia
AO-01/03	ND 01-1396-3-1-1-2	High oleic (91,16% oleic)
BXC 97/01	LC 206020 × MP 555	Resistance to Rust
GP 03/03	A × B-3479-2-2-3/B × C-3495-2-1-1-1-3-3	Resistance to Sclerotinia, MR to Verticillium
GP 01/02	E-1-1-2/DXT 3330-1-1-2-3-3-2	Resistance to Verticillium
GP 02/05	D × T 3330-3-2-4/HA 89-1-4-1	Resistance to Sclerotinia
GP 02/06	HA-89/D × T 3330-3-2-4-1-1-1-3	Resistance to Sclerotinia
GP 03/01	GP-01/02/GP-02/04-1-1-2-1-4	Resistance to Downy mildew (race 770)
GP 03/05	B × C-97/01/KLM-214-2-1-4	Resistance to Verticillium
GP 06/04	LUCH-1-1-1-1-1/AO-01/03 -4-1-1	High oleic (90.8% oleic), MR to Verticillium.
GP 06/02	AO-01/02/B × C-00/01-1-2-4-1	High oleic (93% oleic)
GP 07/07	BZ-3669-2-5-3/KLM-280/HA-300-1-2	Resistance to Verticillium
GP 07/13	VN-02/01/AO-02/01-2-3-2-4-1	High oleic (87% oleic), MR to Verticillium.
GP 07/14	SB-04/01/BZ-3669-2-5-3-2-2-1-1-2-3	Resistance to Verticillium
GP 08/03	VN-02/01/AO-03/15-4-1-1-3-2	Resistance to (87% oleic), MR to Verticillium.
GP 08/05	2341/23(Sel. HA 335/HA412)	Resistance to Downy mildew (race 770), MR to Vert.

(*continued*)

Table 1: (*Continued*)

Line	Origin	Character
GP 08/06	2341/27(Sel. HA 335/HA412)	Resistance to Downy mildew (race 770), MR to Verticillium.
GP 08/07	2341/28(Sel. HA 335/HA412)	Resistance to Downy mildew (race 770)
GP 08/16	V-13/B × C-3496-1-3-3-2-1-4-3	Resistance to Sclerotinia
GP 09/08	VN-02/01/AO-03/15-1-1-2-2-3	Resistance to Verticillium
GP 10/04	2341/27/AO-03/15/BZ-3669-2-5-3-2-2	Resistance to Verticillium
GP 12/05	2341/27/GP-03/03-5-3-3-2	Resistance to Downy mildew (race 770)
GP 12/07	GP-04/01/GP-03/01-3-1-3-2	Resistance a Downy mildew (race 770), MR to Verticillium.
IMI 04/01	2329-1-22-2-3-1	Resistance to Imidazolinone
IMI 04/04	2309-1-5-4-1-1	Resistance to Imidazolinone
IMI 05/04	2330-3-2-2-1-1	Resistance to Imidazolinone
IMI 05/05	2330-3-2-4-3-3	Resistance to Imidazolinone
IMI 09/06	2329-1-7-2-3-1-2	Resistance to Imidazolinone, R to Verticillium
IMI 03/01	2329-5-34-4-1-1	Resistance to Imidazolinone, MR to Verticillium
P4 01/01	P4 C3-22-2-2-7 Compound P4	Resistance to Verticillium
RK 416	Compound PGRK	Resistance to Sclerotinia
RK 426-11	Compound PGRK	Long Cycle
S 32	Synthetic Os2	Long Cycle
MP 83/2	Mezcla Precoz (Russian × Wild)	Short Cycle
P1 01/01	60-10-5-1 Compound P1	Short Cycle
VN 02/01	VNIIMK 1646	Resistance to Verticillium
VN 03/02	VNIIMK 1646	Resistance to Verticillium
RK 489	Compound PGRK	Resistance to birds
S 74	Sintética Os2	Resistance to birds
RK 456	Compound PGRK	Resistance to birds

Notes: Verticillium: *Verticillium dahliae*; Downy mildew (*Plamophara halstedii*), race 5(770), race 2(300); Sclerotinia: *Sclerotinia sclerotiourum*; MR: moderately resistant; R: resistant. Rust: *Puccinia helianthi*.

three of which were also moderately resistant to Verticillium. Ten lines were resistant to Sclerotinia (one of which was also moderately resistant to Verticillium and another had high oleic acid content) and two lines were resistant to stalk rot. Fifteen lines with high oleic acid content were obtained (three of which were also moderately resistant to Verticillium and one moderately resistant to Sclerotinia).

Ten imidazolinone resistant lines were obtained (two of which were resistant to Verticillium and one was moderately resistant to Verticillium).

Table 2: Lines developed at INTA Manfredi with different improved characters.

Line	Origin	Character
A445	Wild germplasm of origin JFJ2275-U5	Resistance to Verticillium
MF42-3	Puntano × Smena (A10)/A5439_07	Resistance to Verticillium
R 82-11-17	Compound *Rf* Yugoslavia/Manfredi	Resistance to Downy mildew (race 300)
R 79-73-421	Compound *Rf* Yugoslavia/Manfredi	Resistance to Downy mildew (race 300)
R 79-25-1522-2	compound *Rf* Australia/Manfredi	Resistance to Downy mildew (race 300)
A 71	HA 335 × sel.Peredovick (B83-3)	Resistance to Downy mildew (race 770)
A 249	HA 335) × sel.Puntano/Smena (B09)//Impira sel.427 (B03)	Resistance to Downy mildew (race 770)
A251	HA 335) × sel.Puntano/Smena (B09)//Impira sel.(B03)	Resistance to Downy mildew (race 770)
A263	HA 335) × sel.Comangir (B06)//Impira Sel.427 (B03)	Resistance to Downy mildew (race 770)
A273	HA 335) × sel.Guayacán (B17)/Cruso/ Manfredi (B59)	Resistance to Downy mildew (race 770)
C192	Variety of Romanian origin, Sel.B2	Resistance to Sclerotinia
AC769	Compound B Lines USA	Resistance to Sclerotinia
R381	A83-3 X Compound Rf lines high oleic USA	Resistance to Sclerotinia, High oleic
R393-E	A83-3 X Compound Rf lines high oleic USA	Resistance to Sclerotinia
B3796_09	Variety of Russian origin, Ella, Sel-1	Resistance to basal stem rot
R3889_09	A83-3 X el Compound B Lines USA C811-15/C829	Resistance to basal stem rot
A09	Población Puntano/Smena Sel.81-45	Resistance to Rust
A99	Poman-Sel91-123-2	Resistance to Rrust
A105	Poman-Sel91-123-3	Resistance to Rust
A109	Poman-Sel91-123-5	Resistance to Rust
A115	Poman-Sel91-123-8	Resistance to Rust
R313	Pehuén/Caburé//Charata-SelRN160	Resistance to Rust
A91	Guayacán-Sel.B76-2/X Compound B lines high oleic 92	High oleic
A123	B83-3/HA342	High oleic
A95	Guayacán-Sel.B76-2/Compound B lines high oleic 92	High oleic
R285	Sel. Compound Rf high oleic 92	High oleic
R383	A83-3/RG-98-659-4	High oleic
A499	B10//B83-3/HA425	Resistance to Imidazolinone
A505	B10//B83-4/HA425	Resistance to Imidazolinone
R839	A83-3/RfI-1	Resistance to Imidazolinone

(*continued*)

Table 2: (*Continued*)

Line	Origin	Character
R845	A83-4/RfI-1	Resistance to Imidazolinone
CB S9.1	Puntano × Smena B09/germplasm naturalized Argentine Sd10	Resistance to virus diseases (SuMCoV)
CR S1.0ME	Puntano × Smena A09/germplasm Argentine naturalized S10c//germplasm Argentine naturalized S10c	Resistance to virus diseases (SuMCoV)
CR S12.0	Germplasm naturalized Argentine S10c/ derived from PuntanoxSmena B09.	Resistance to virus diseases (SuMCoV)
A71	B83-3/HA335	Tolerance to water stress
R432	HA89/RHA274/91T608 (wild germplasm of French origin)//R049	Tolerance to water stress
A10	Selection of the population Puntano	Long Cycle
R049	A83-4/R79-25-1522-2	Long Cycle
R307	A83-3/RHA361	Long Cycle
A83-3	Selection of Peredovick	Short Cycle
A59	(Peredovick/Cernianka)/Manfredi (Cordobés/Impira)	Short Cycle
R 79-15-622-2	Compound *Rf* USA_Sel SB254/Guay (B76-2)	Short Cycle
R 79-15-631-1	Compound *Rf* USA_Sel SB254	Short Cycle
R023	A83-3/Compound *Rf* Australia-HS101 Sel. R79-13-232-1	Short Cycle
R239	R USA-Sel.R88-189-53	Short Cycle
R021X	A83-3/Compound *Rf* USA	Short Cycle
A67	Selection of the NSP Yugoslav population	Bird consumption
A101	Population of Israel-V1/Impira origin	Confectionery
A102	B101/BNDNOB5 Sel-1 USA	Confectionery
A333	B101/BHA351 USA	Confectionery
A355	B101/BNDNOM3 USA	Confectionery
R403	A101/Compound *Rf* lines confectionery USA-Sel.G99-661-3	Confectionery
R401	A101/Compound *Rf* lines confectionery USA-Sel G99-662-4	Confectionery

Notes: Verticillium: *Verticillium dahliae*; Downy mildew: (*Plasmopara halstedii*), raza 5(770), raza 2(300); Sclerotinia.: *Sclerotinia sclerotiourum*; MR: moderately resistant, R: resistant. Rust: *Puccinia helianthi*.

Three lines resistant to viral diseases were obtained. Seven rust resistant lines, two stalk rot resistant lines, two water stress tolerant lines, three bird tolerant lines, ten short cycle lines, four long cycle lines, six for confectionary and one for bird consumption were also obtained.

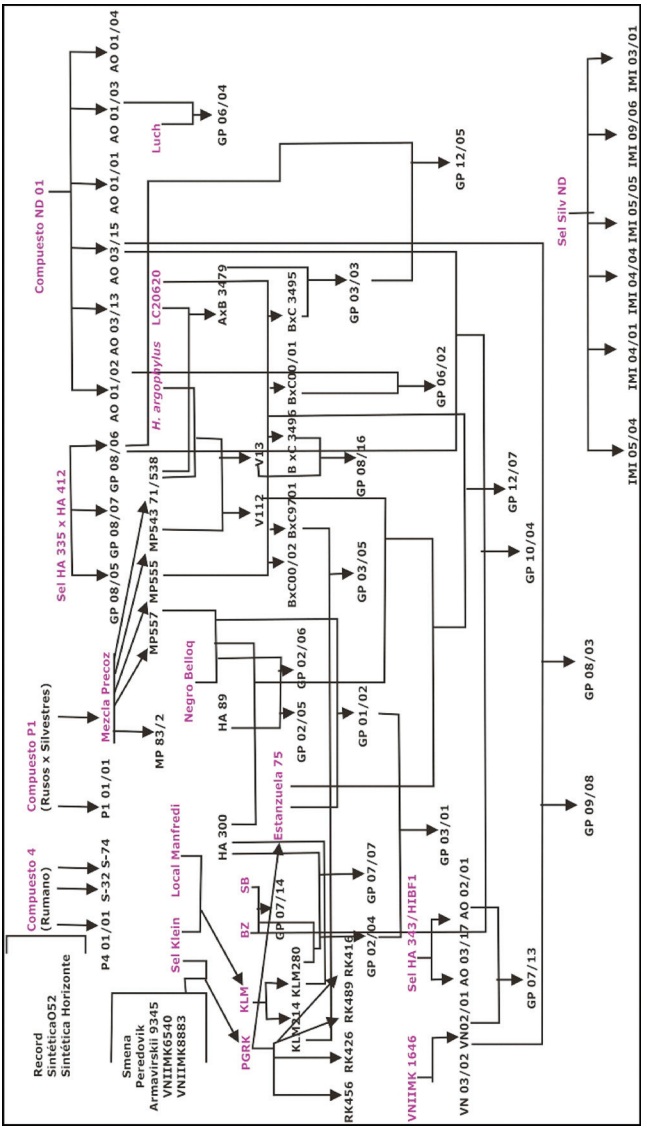

Figure 1: Origin of the lines obtained in INTA Pergamino.

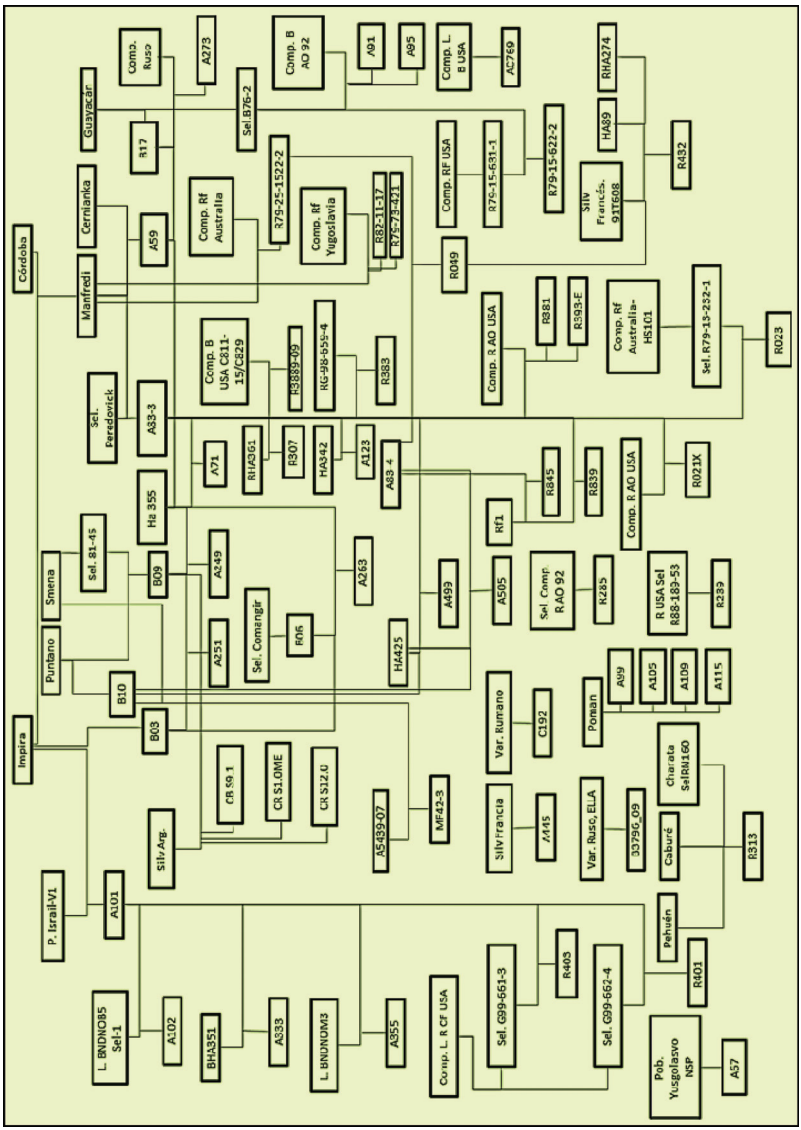

Figure 2: Origin of the lines obtained by INTA Manfredi.

There was a wide variability in the germplasm used for the improvement of different characters. This gives an important strength to reduce the vulnerability of the crop associated to highly related germplasm.

Part II: Sunflower lines resistant to diseases and birds originated from INTA genetic material[2]

Downy mildew (*Plasmopara halstedii* (Farlow) Berlese & de Toni)

HA-R4

HA-R4 is a Downy mildew differential line used internationally. It was obtained by Dr. Tom Gulya in 1984 at USDA, Fargo, North Dakota, from the Selection Sáenz Peña 74-1-2. This SP74-1-2 comes selected from a large compound consisting of: Early Mix (Mezcla Precoz) + PGRK + Romanian Compound (Figure 3). The line HA R4 has the gene for resistance to Downy mildew *Pl16* (Liu *et al.*, 2012).

In Canada in the year 2010, HA-R4 was resistant to the present races of Downy: 120, 320, 400, 520, 700, 720, 730 and 770.

HA-R4 is resistant to the races of Downy mildew 100, 300, 304, 330, 334, 700, 710,714, 730, 734 and 770 and susceptible to 703 and 733 (de Romano *et al.*, 2010).

In Canada HA-R4 is susceptible to race 731 and resistant to races 502, 702, and 722. In North America it was resistant to 732 and 772 races (Liu *et al.*, 2012).

HA-R5

HA-R5 is a Downy mildew differential line obtained from Guayacan INTA Selection Castelar in 1984 by Dr. T. Gulya in USDA Fargo, North Dakota (Figure 4). This differential line has the gene for resistance to Downy mildew *Pl13* (Mulpuri *et al.*, 2009).

HA-R5 in Canada in the year 2010 was resistant to prevalent races that year: 120, 320, 400, 520, 700, 720, 730 and 770.

HA-R5 was resistance to race 731 and was susceptible to the races 502, 702, 722,732 y772 of Downy mildew (Gulya *et al.*, 2011).

HA-R5 is also resistant to the races 100, 300, 304, 330, 334, 700, 710, 714, 730, 734 and 770 and susceptible to 703 and 733 races (de Romano *et al.*, 2010).

FT226 (QHP 1)

Performed at INRA, France in 1994, fertility restorer line (experimental code QHP 1) resistant to several races of Downy mildew: 100, 300, 304 (00), 304 (02), 314,

2 Author of the Part II: Vázquez, A.

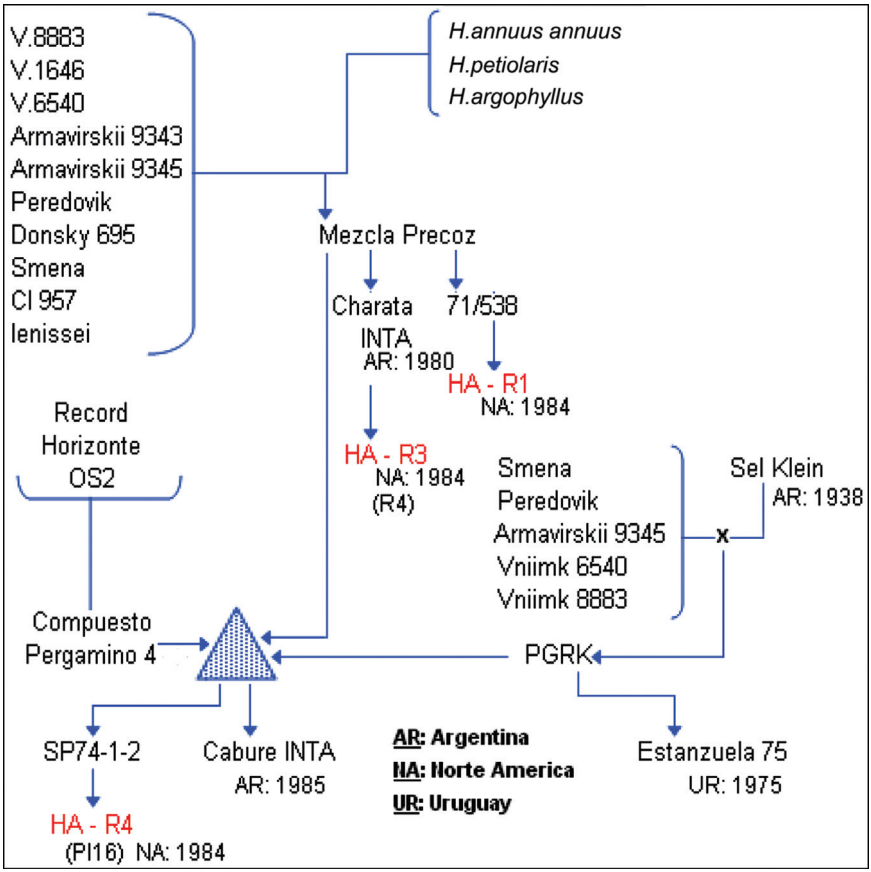

Figure 3: Map that shows the pedigree of sunflower lines originated from INTA germplasm.

330, 334, 700, 704, 710, 714, 730 and 774 (Tourvieille de Labrouhe *et al.*, 2012). QHP1 comes from the crossing of lines HA-R5 and PRS7 conducted at INRA (Figure 4).

FT326 (QHP2)

Performed in INRA France in 1999, fertility restorer line, QHP2 (experimental code), their genetic origin is HA-R5 line crossed with material from the program of tolerance to Sclerotinia (Agri obtentions, 2007) (Figure 4).

In France, QHP 2 gives resistance to races of Downy mildew 100, 300, 304 (00), 304 (02), 314, 330, 334, 700, 704, 710, 714, 730, and 774 and it is susceptible to 307, 703, 707 and 717 races (Tourvieille de Labrouhe *et al.*, 2012).

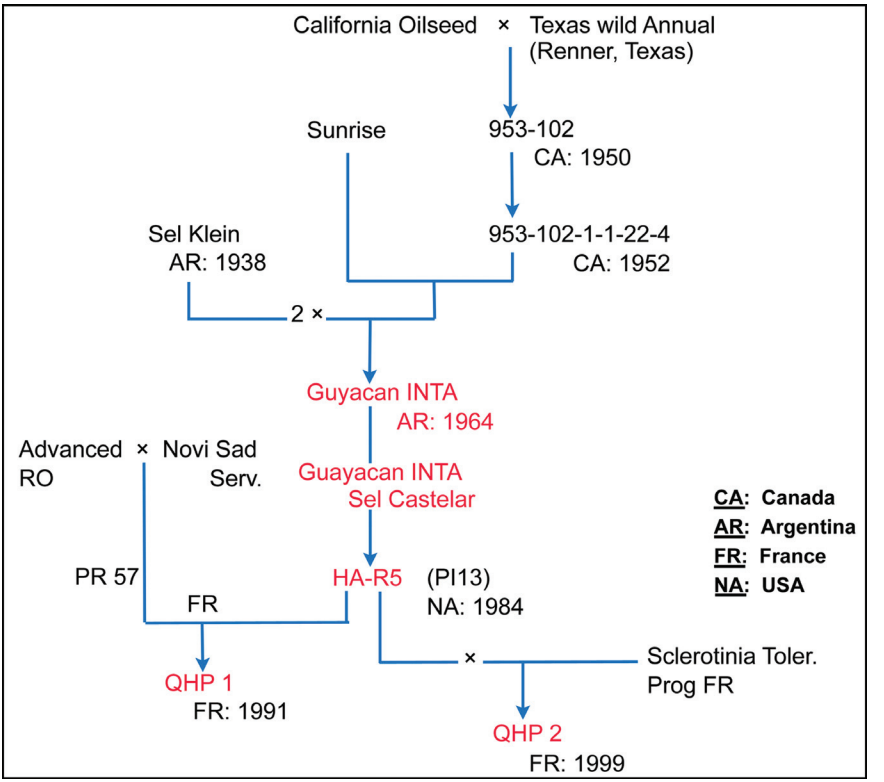

Figure 4: Origin of Guayacan INTA variety and the sunflower derived lines.

Rust *Puccinia helianthi* Schw.

HA-R1 (GP24)

Rust differential line selected from the line 71/538 of INTA Pergamino. Obtained by Dr. T. Gulya at USDA, Fargo, North Dakota in 1984 (Gulya, 1985). Pergamino 71/538 was originated from Mezcla Precoz or Early Mix (Figure 3) obtained by M. Davreaux at INTA Pergamino in 1955/56 (de Romano and Vazquez, 2003). Also is resistant to Verticillium.

In Canada HA-R1 in 2007 was susceptible to rust prevalent races in the great culture: 320, 324, 326, 336, 337,724, 726, 734 and 736 and resistant to race 304 (Rashid, 2008).

In Argentina, HA-R1 is resistant to rust races present in the field: 700, 704, 740, 744, and susceptible to 720 and 760 races (Moreno *et al.*, 2012).

HA-R2 (GP-25)

Differential rust line, originated in Impira INTA Selection 5 Castelar (Figure 5). It was selected by Dr. T. Gulya in 1984 in the USDA, Fargo, North Dakota. It is of head pendulum and striped seeds (Gulya, 1985). It has the gene for resistance to rust R5 (Qi *et al.*, 2012). Also is resistant to Verticillium.

In Australia the HA-R2 line showed resistance to most races of rust appeared for 25 years (Sendall *et al.*, 2006), the same occurring with MC 29 a Canadian line.

In Canada in 2007 the line HA-R2 was resistant to the races of rust, 304, 320, 324, 326, 336,337,536, 724, 726, 734, 736 and 737 and susceptible to 377 and 774 races (Rashid, 2008).

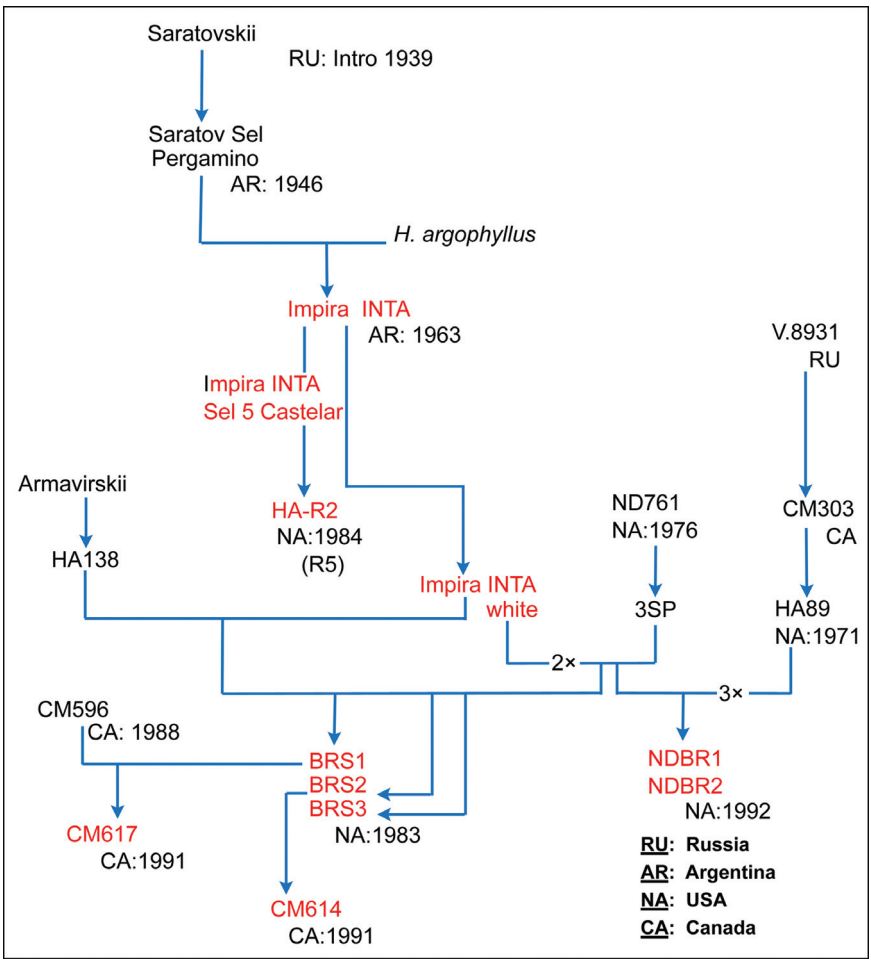

Figure 5: Origin of Impira INTA and the sunflower derived lines.

In Argentina HA-R2 is susceptible to the races 700, 704 and 720 and susceptible to 740 and 744, 760 (Moreno *et al.*, 2012).

HA-R3 (GP26)

Rust differential line, selected by Dr. T. Gulya from Charata INTA (Figure 3) (Gulya, 1985). Charata INTA variety was obtained in 1980 by Tcach and Davreaux from Mezcla Precoz (de Romano and Vazquez, 2003). It has R3 and R4 genes highly effective for rust resistance (Qi *et al.*, 2011). The R4 gene is being introduced in sunflowers confectioners by scientists at USDA ARS, NCSL, Fargo, ND-NDSU-Plant Pathology Fargo, ND, since it gives resistance to race 336 and moderate resistance to race 777, both widespread in the USA (Gong *et al.*, 2011).

HA-R3 is susceptible to rust races 337, 377 and 737 and resistant to the other races present in 2007 in Canada: 304, 320, 324, 326, 336,536, 724, 726, 734 and 736 (Rashid, 2008).

In Argentina HA-R3 provides resistance to all present races currently: 700, 704, 720,740, 744 and 760 (Moreno *et al.*, 2012).

HA-R4 (GP27)

HA-R4 is a rust differential line obtained by Dr. T. Gulya in 1984 in the USDA, Fargo, North Dakota from selection "Sáenz Peña 74-1-2" (Figure 3). HA-R4 is tall, brown seeds with white striped (Gulya, 1985), also has resistance to Downy mildew. Sáenz Peña 74-1-2 comes from the compound formed by Mezcla Precoz + PGRK + Romanian compound (de Romano and Vazquez, 2003).

Sáenz Peña 74-1-2 gave immunity to races 1, 2, 3 and 4 (universal designation 100, 500, 300 and 700) in artificial inoculations with rust (Yang *et al.*, 1986).

HA-R4 has gave strength in 2007 to the races of rust, 304, 320, 324, 724, 734, and 774 and susceptible to 326, 336, 337, 536, 726, 736 and 737 in Canada (Rashid, 2008).

In Argentina HA-R4 is resistant to the races of rust present: 700, 704, 720, 740, 744 and 760 (Moreno *et al.*, 2012).

HA-R5 (GP28)

HA-R5 is a rust differential line created by Dr. T. Gulya in 1984 at USDA, Fargo, North Dakota from Guayacan INTA Selection Castelar (Figure 4). Black seeds with white striped (Gulya, 1985). HA R5 has the gene for resistance to Downy mildew *Pl13* (Mulpuri *et al.*, 2009) and is used as a differential for this disease.

In 1985 Guayacan INTA Sel.Castelar, was resistant to races 1 and 2 (universal designation 100 and 500) and susceptible to the races 3 and 4 of rust (univ. design. 300 and 700) (Yang *et al.*, 1986). These results are consistent with the reaction of the line 953-102-1-1-22-4 possessor of the R1 gene and that gave resistance to Guayacán INTA (Figure 4).

HA R5 is resistant to race 320 in Canada and susceptible to the other races present in that country: 304, 324, 326, 336, 337,536, 724, 726, 734 and 736, 737 and 774 (Rashid, 2008).

In Argentina HA R5 is resistant to races 700, 720, 740, 760 and susceptible to 704, and 744 (Moreno *et al*., 2012).

HA 369 (GP 116)

HA 369 is a maintainer line obtained by the USDA-ARS and ND Agricultural Experimental Station, Fargo, ND, in 1988, by Miller, J.F. and Gulya, T.J. It was obtained from the selection 8018 from INTA Manfredi. HA369 is a vigorous, resistant to the rust original 1, 2 and 3 (univ. designation 100, 500 and 300) and susceptible to the 4 (univ. designation 700) (Miller and Gulya, 1990). 8018 selection was carried out in 1976 in INTA Manfredi, and its creators were Bauer, Areco and Alvarez (de Romano and Vazquez, 2003).

Verticillium wilt, variegated leaf, *Verticillium dahliae Kleb*.

Three lines, HA-R1, HA-R2 and HA-369, whose origins in INTA materials and authors have already been mentioned, are, according to reports from breeders resistant to *Verticillium dahliae Kleb*. (Figures 3 and 5).

Estanzuela 75

The Agricultural Research Center "Alberto Boerger" of the Oriental Republic of Uruguay in 1975 released the sunflower variety Estanzuela 75 obtained by recurrent selection from the (Russian × Klein) compound of the INTA Pergamino (PGRK), received in 1970 from the Experimental Station of Pergamino, Argentina.

Held selection for performance, cycle, uniformity in height, rust resistance and *Verticillium* (De Leon, 1975).

Sunflower lines originated in INTA resistant to birds

BRS-1, BRS-2 and BRS-3

They are synthetic resistant to birds, developed in 1983 by North Dakota Agricultural Experimental Station, USDA-ARS and US Department of Interior Fish & amp; Wild life Service. They come from the crossing between Impira INTA White (selection of Impira), crossed with 3SP (reselection of ND761, resistant to downy mildew, gene *Pl2*) and HA138 (derived from Armavirski) (Figure 5).

Impira INTA variety was made in INTA Manfredi in 1963 (de Romano and Vazquez, 2003).

BRS-1 is a compound selected by white seeds or plants with few stretch marks, rolled bracts and elongated neck of the plant, blooming in 67–73 days.

BRS-2 is a compound with characteristics similar to BRS-1 but that it blooming in 84–87 days.

BRS-3 is a compound of white seed with few stretch marks, little rolled bracts, little concave heads and blooming in 67–73 days (USDA, ARS, National Genetic Resources Program GRIN 2014).

NDBR1 and NDBR2

These two lines are maintainers developed by the USDA-ARS and the ND Agricultural Experimental Station in May 1992. They come from the cross of Impira INTA White × 2/3SP/3/HA89 (Figure 5).

Both lines have concave heads, inclined and away from the stem. They are resistant to race 2 (univ. designat: 300) original of Downy mildew, and susceptible to rust (Hanzel *et al.*, 1993).

CM 617

Restorer of fertility line developed in Manitoba, Canada, in 1991 by Dr. Dedio W. from synthetic BRS-1 of North Dakota, resistant to birds, crossed by the restorer line CM596 from Canada (3 map origin). CM617 is a branched line, resistant to downy mildew original race 2(univ. designat: 300), rust original race 1 (univ. designat: 100) and *Verticillium* (USDA, ARS and GRIN, 2014).

CM 614

CM614 is a resistant to birds line preformed by selection in the synthetic BRS2 of North Dakota. The synthetic BRS2 derived from crosses with Impira INTA White (Figure 5). The CM614 line was selected by the Dr. Dedio, W. from Manitoba, Canada. It is of medium height, head decumbent and white achenes. Downy mildew, *Verticillium* and rust resistant (USDA, ARS and GRIN, 2014).

Conclusions

The germplasm developed by INTA made significant contributions to breeding programs in Argentina and also worldwide. In United States of America, using by exchange the sunflower genetic material from INTA were registered and made available to breeders; five rust differential lines, one rust-resistant

Table 3: Origin and resistance to different downy mildew and rust physiological races of sunflower lines originated with INTA germplasm.

Line	Origin	Resistance and genes	Physiological races to which it's resistant in each country
HA-R4	SP 74-1-2	Downy mildew: gen *Pl16*	AR: 100, 300, 304, 330, 334, 700, 710, 714, 730, 734, 770 (de Romano *et al*., 2010) CA: 502, 702, 722 (Zhao Liu *et al*., 2012) and 120, 320, 400, 520,700, 720, 730 and 770 (Rashid, 2010) NA: 732, 772 (Liu *et al*., 2012)
HA-R5	Guayacán INTA Sel Castelar	Downy mildew: gene *Pl13*	AR: 100, 300, 304, 330,334, 700, 710, 714, 730, 734, 770 (de Romano *et al*., 2010); NA: 731 (Gulya *et al*., 2011); CA: 120, 320, 400, 520, 700, 720, 730 and 770 (Rashid, 2010)
QHP1	HA-R5 × PRS7	Downy mildew	FR: 100, 300, 304(00), 304(02), 314, 330, 334, 700, 704, 710, 714, 730, 774 (Tourvieille de Labrouhe *et al*., 2012)
QHP2	HA-R5 × Prog. Tol.Scler.	Downy mildew	FR: 100, 300, 304(00), 304(02), 314, 330, 334, 700, 704, 710, 714, 730, 774 (Tourvieille de Labrouhe *et al*., 2012)
HA-R1	Pergamino 71/538	Rust	AR: 700, 704, 740, 744 (Moreno *et al*., 2012); CA: 304 (Rashid, 2008)
HA-R2	Impira INTA Sel.5 Castelar	Rust: gene *R5*	AR: 700, 704, 720 (Moreno *et al*., 2012); CA: 304, 320, 324, 326, 336, 337, 536, 724, 726, 734, 736, 737 (Rashid, 2008)
HA-R3	Charata INTA	Rust: gene *R4*	AR: 700, 704, 720, 740, 744, 760 (Moreno *et al*., 2012;); CA: 304, 320, 324, 326, 336, 536, 724, 726, 734, 736 (Rashid, 2008)
HA-R4	SP 74-1-2	Rust	AR: 700, 704, 720, 740, 744, 760 (Moreno *et al*., 2012); CA: 304, 320, 324, 724, 734, 774 (Rashid, 2008)
HA-R5	Guayacán INTA Sel Castelar	Rust	AR: 700, 720, 740, 760 (Moreno *et al*., 2012); CA:320 (Rashid, 2008)
HA 369	Sel.8018	Rust	NA: Originales 1, 2 and 3 (Miller and Gulya, 1990) (univ.desig. 100,500,300)

AR: Races present in Argentina FR: Races present in France; CA: Races present in Canada NA: Races present in United States of America.

maintainer line, one downy mildew differential line (Table 3) and three synthetic and two birds-resistant maintainer lines (Figure 5).

In France, at INRA, two downy mildew differential lines were achieved using lines developed by the USDA with INTA germplasm (Figure 4).

In Canada, a restorer and a maintainer line, both bird resistant, were obtained using material made in USDA with a variety of INTA (Figure 5).

In Uruguay the Estanzuela 75 variety was obtained.

Materials from INTA are: variety Charata INTA (Figure 3), Guayacán INTA Castelar (Figure 4) selections; Impira INTA sel.5 Castelar (Figure 5); Sáenz Peña 74-1-2, Pergamino 71/538, selection 8018, (Table 3) and the Early Mix and PGRK (Figure 3) populations.

These materials of INTA were developed at experimental stations of Pergamino, Manfredi, Sáenz Peña and Castelar.

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