Description of cultivar

Ágata: a new variety of oats (*Avena sativa* L.) for the production of grain in Mexico

Héctor Eduardo Villaseñor Mir[1]
Eduardo Espitia Rangel[1]
Julio Huerta Espino[1]
Leodegario Osorio Alcalá[2]
René Hortelano Santa Rosa[1§]
Eliel Martínez Cruz[1]
María Florencia Rodríguez García[1]

[1]Valley of Mexico Experimental Field-INIFAP. Highway Los Reyes-Texcoco km 18.5, Coatlinchán, Texcoco, State of Mexico. CP. 56250. Tel. 01 (800) 0882222, ext. 85357. [2]Valleys Centrals of Oaxaca Experimental Field-INIFAP. Melchor Ocampo num. 7, Santo Domingo Barrio Bajo, Etla, Oaxaca. CP. 68200. Tel. 01 (800) 0882222, ext. 86706. (osorio.leodegario@inifap.gob.mx).

[§]Corresponding author: hortelano.rene@inifap.gob.mx.

Abstract

During the last five years, the area planted with oats in Mexico has fluctuated from 700 000 to 800 000 ha. In 2015, the area sown with oats (*Avena sativa* L.) in Mexico was around 800 thousand hectares. The new variety Ágata is a spring habit and was developed in the Valley of Mexico Experimental Field of the National Institute of Forestry, Agriculture and Livestock Research through the crossing of line A: KAR/GAL//ZAF/KAR with line B:BLEN/KAR, its genealogy is KAR/GAL//ZAF/KAR/3/BLEN/KAR and its pedigree is I-4533-0C-12C-0R-0C-3C-0R. The new Ágata variety was tested during the years 2011 to 2015 together with 11 witnesses in temporary conditions in 81 environments. The average of its grain production was 2.7, 4.2, 2.8 and 1.2 t ha^{-1} in general, favorable environments, intermediate and critical production, respectively, higher than all the witnesses used from 14% (Turquesa) to 56% (Ópalo), the greatest advantage in its yield with respect to the control varieties was in intermediate production environments, where more appropriate conditions prevail for the incidence of stem rust. Ágata is a medium-cycle variety, intermediate plant and moderately resistant to lodging, which has resistance to moderate resistance to stem rust and leaf rust, showing a higher level of resistance than all control varieties, and is tolerant to foliar disease complex. It is recommended for seasonal sowing in the different oat producing regions in Mexico.

Keywords: adaptation, varieties of oat, yield.

Reception date: May 2018
Acceptance date: June 2018

During the last five years, the area planted with oats in Mexico has fluctuated from 700 000 to 800 000 ha (SIAP, 2016), an increase attributed to the fact that this cereal is better adapted to drought conditions and low temperatures compared to corn and beans, wheat or barley (Villaseñor *et al*., 2015), turning oats into the main alternative crop when there are disasters in the aforementioned or when it is no longer convenient to plant them. In the country, 90% of the area sown with oats is destined to the production of forage in its different forms and 10% for grain production; likewise, 81.7% of their plantings are made under rainfed conditions and 18.3% under irrigation conditions.

Stem rust (*Puccinia graminis* f. sp. *avenae* Eriks. and Henn.) is the main limiting factor in the production of oats, a disease that can cause losses of up to 70% (Leyva *et al*., 2004) in susceptible varieties, is considers that the most effective way to control this disease is through the planting of resistant or tolerant varieties (Roelfs *et al*., 1992; Huerta-Espino and Singh, 2000), a strategy that has maintained the oat genetic improvement program of the National Institute of Forestry, Agriculture and Livestock Research (INIFAP) (Villaseñor *et al*., 2015) since 1960 and now available to farmers and the oat processing industry the variety Ágata, which has stood out in more than 81 evaluations national level for its high grain yield and for its reaction to stem rust that was resistant (R) to moderately susceptible (MS), to the different races of stem rust that have prevailed in the country during the evaluation period from 2011 to 2015, which according to Mariscal *et al*. (2011) are more than 11 different races.

Origin and characteristics

The variety of oats Ágata is of habit of spring, intermediate cycle (108 days to physiological maturity on average), medium height (97 cm on average), is tolerant to lodging, resistant to moderately resistant to stem rust and rust of the crown (*Puccinia coronata* f. sp. *avenae*), tolerant to foliar disease complex and responds favorably in any type of production environment under temporary. This variety was generated in the Oats Genetic Improvement Program of the National Institute of Forestry, Agriculture and Livestock Research (INIFAP) based in the Valley of Mexico Experimental Field (CEVAMEX), through a process that included genetic recombination, selection and evaluation. The variety was obtained through a simple cross identified with the number I-4 533 and the application of the combination of mass or population selection methods and that of derived families. The mass was used under the principles of the gravimetric method for the selection of grain with greater weight. Next, the obtaining process is described.

The crossing was carried out in Spring-Summer (SS) 1999, the F_1 was evaluated in Autumn-Winter (AW) 1999-2000 and its cross was identified with the number 4 533, the F_2 was planted in SS-2000 and it was applied selection under the gravimetric method, in F_3 the plant number 12 was selected, in F_4 the family number 185 was harvested massively, in F_5 the family number 96 was massively harvested, in F_6 the plant number 3 was harvested individually and in F_7 it was harvested massively the uniform line (Table 1), which was identified with the following genealogy and pedigree:

Genealogy: KAR/GAL//ZAF/KAR/3/BLEN/KAR
Pedigree: I-4533-0C-12C-0R-0C-3C-0R

Table 1. Process of obtaining the Ágata variety.

Agricultural cycle/site	Genealogy/generation
S-S/1999 in Chapingo, Mex.	Line A: KAR/GAL//ZAF/KAR
	Line B: BLEN/KAR
	Crosses: KAR/GAL//ZAF/KAR/3/BLEN/KAR
A-W/1999-2000 in Chapingo, Mex.	F_1: cross selection 4533.
S-S/2000 in Chapingo, Mex.	F_2: sowing in full competition and population selection 4533 "gravimetric method" (0C)
S-S/2001 in Chapingo, Mex.	F_3: planting a spaced plant and individual selection of plant No. 12 (12C)
A-W/2001-2002 in Roque, Gto.	F_4: planting in full competition, selection and harvest of family No. 185 (0R)
S-S/2002 in Chapingo, Mex.	F_5: sowing in full competition, selection and harvest of family No. 96 (0C)
S-S/2003 in Chapingo, Mex.	F_6: planting a spaced plant and individual selection of plant No. 3 (3C)
A-W/2003-2004 in Roque, Gto.	F_7: planting in full competition and selection of uniform line (0R)

A-W= Autumn-Winter; S-S= Spring-Summer; F_1-F_6= filial generations of segregation; F_7= uniform line.

As of the summer of 2005, the experimental line was evaluated in the different tests. It was initially tested in the preliminary performance test (PPR) in localities of the State of Mexico, Puebla, Hidalgo and Tlaxcala. Subsequently, from 2006 to 2010, it was included in the respective oat selection nurseries (VISAVENA) and from 2011 to 2015 it was evaluated in the eleventh to fifteenth national uniform test of oats (11^{th} EUAVENA to the 15^{th} EUAVENA), respectively, in up to 81 localities located in 11 states of the Mexican Republic that included Aguascalientes, Chihuahua, Durango, State of Mexico, Guanajuato, Hidalgo, Jalisco, Oaxaca, Puebla, Tlaxcala and Zacatecas.

Reaction to rusts and foliar diseases

Ágata is resistant to moderately susceptible to stem rust (*Puccinia graminis* f. sp. *avenae*), is resistant to moderately resistant to crown or leaf rust (*P. coronata*) and is tolerant to the foliar disease complex caused by *Helminthosporium avenae* (leaf spot), *Septoria avenae* f. sp. *avenae* (leaf spot) and *Colletotrichum graminicola* (anthracnose).

Table 2 shows the reaction to diseases of Ágata and control varieties after 81 evaluations under temporary. Stem rust recorded readings from 0 to 30MR, a type of reaction less than Turquesa that in some places reached readings of up to 60S; likewise, it also presented lower readings than the other control varieties that already present a susceptibility reaction with percentages from 50% to 100% of infection. In crown or leaf rust Ágata was the genotype with the greatest resistance, since it presented incidences of TR at 20MS, lower than Turquesa, as well as the rest of the witnesses that had incidences of 50% up to 100% susceptibility reaction to said disease, with the exception of Diamond R31, which continues to show good tolerance.

Table 2. Agronomic and phytopathological characteristics of Ágata and of control varieties in rainfed environments from 2011 to 2015.

Variety	Cycle	Height (cm)	Acame	Stem rust	Crown rust	Foliars *
Ágata	Intermediate	98	MR	0R to 30MR	TR to 20MS	6/40 (T)
Turquesa	Intermediate	97	MR	30MS to 60S	10R to 30MS	6/40 (T)
Obsidiana	Intermediate	97	MR	10MS to 60S	20MS to 70S	5/20 (T)
Karma	Intermediate	95	R	10MS to 50S	10R to 50S	6/40 (T)
Avemex	Late	111	MS	20MS to 80S	20MS to 70S	6/40 (T)
Menonita	Early	93	R	10MS to 80S	20MS to 70S	7/60 (MS)
Papigochi	Intermediate	92	MR	5MR to 70S	20MR to 70S	7/60 (MS)
Chihuahua	Late	98	S	60S to 100S	50S to 100S	6/40 (T)
Ópalo	Late	107	S	70S to 100S	60S to 100S	6/30 (T)
Cuauhtémoc	Late	106	MR	60S to 100S	50S to 100S	6/40 (T)
Diamante R31	Early	97	R	5R to 40MR	10R to 20MS	6/40 (T)
Teporaca	Early	100	S	10MS to 80S	20MS to 70S	6/40 (T)

R= resistant; S= susceptible; MR= moderately resistant; MS= moderately susceptible; TR= traces; T= tolerant, observed readings; *= maximum observed reading of reaction to the complex of foliar diseases in rainy environments (Nanacamilpa, Tlax and Juchitepec, State of Mexico), caused by *Helminthosporium avenae* (leaf spot), *Septoria avenae* f. sp. *avenae* (leaf spot) and *Colletotrichum graminicola* (anthracnose).

In areas with higher altitude and higher incidence of rainfall, foliar diseases occur more aggressively because these sites have humidity and temperature conditions conducive to their development (Prescott *et al*., 1986). The Ágata variety equated tolerance to these diseases with most of the control varieties, showing greater tolerance than the susceptible varieties Papigochi and Menonita; due to its tolerance to these pathogens, Ágata is a good option to be recommended in this type of environment (Table 2).

Grain yield potential

In the Table 3 shows the comparison of the yield of Ágata grain and the control varieties in 81 evaluations carried out in 11 states of the country that were located from Oaxaca to Chihuahua. In general, Ágata exceeded the grain yield of all varieties from 14% (Turquesa) to 56% (Ópalo), observing that as the variety was more susceptible to stem rust, Agatha was better.

Favorable environments (Fav.) (23 environments with a yield greater than 3 000 kg ha^{-1}): Calera, Zac. 2012; Chapingo, Mex. 2011, 2014, 1F 2015, 2F 2013, 2F 2015; Coatepec, Mex. 2011, 2012, 2F 2013; Huamantla, Tlax. 2012; Jilotepec, Mex. 2011; Juchitepec, Mex. 2011, 2014, Mixteca, Oax. 2014; Nanacamilpa, Tlax. 2011, 2012, 2014, 2015; Roque, Gto.; Sta. Lucia, Mex. 1F 2011, 2012; Yanhuitlan, Oax. 2012, 2014.

Table 3. Ágata grain yield and (%) differences with control varieties in different rainfed environments during 2011 to 2015.

Variety	General	(%) Dif.	Favorable	(%) Dif.	Intermediates	(%) Dif.	Critics	(%) Dif.
Ágata	2 755 a		4 272 a		2 896 a		1 460 a	
Turquesa	2 374 ab	-14	3 622 ab	-15	2 364 b	-18	1 337 ab	-8
Teporaca	2 173 bc	-21	3 084 bc	-28	2 338 b	-19	1 211 abc	-17
Obsidiana	2 129 bc	-23	3 332 abc	-22	2 141 bc	-26	1 142 abc	-22
Karma	2 022 bcd	-27	3 205 bc	-25	1 993 bcd	-31	1 071 abcd	-27
Menonita	1 909 cd	-31	2 784 bcd	-35	1 925 bcd	-34	1 076 abcd	-26
Chihuahua	1 872 cd	-32	2 706 bcd	-37	1 886 bcd	-35	1 136 abc	-22
Papigochi	1 763 cd	-36	2 746 bcd	-36	1 631 cde	-44	1 081 abc	-26
Diamante R31	1 729 cd	-37	2 615 cd	-39	1 700 cde	-41	1 026 bcd	-30
Cuauhtémoc	1 627 de	-41	2 487 cd	-42	1 621 de	-44	908 cd	-38
Avemex	1 608 de	-42	2 450 cd	-43	1 515 de	-48	941 cd	-36
Ópalo	1 222 e	-56	1 787 d	-58	1 243 e	-57	683 d	-53
Tukey (α= 0.05)	451		998.3		513		394	

Intermediate environments (Inter.) (29 environments with performance between 1 500 to 3 000 kg ha^{-1}): Chapingo, Mex. 2012, 1F 2013; Chimalpa, Hgo. 2012; Coatepec, Mex. 1F 2013, 2014, 2015; Cusihuiriachi, Chih. 2011; Fco. I.Madero, Tlax. 2015; Jesus Maria, Jal. 2012; The Concepcion, Pue. 1F and 2F 2013; Roque Gto. 2011; San Pedro Xula, Oax. 2012; Sta. Lucia, Mex. 2014, 1F 2013, 2F 2011; Sinaxtla, Oax. 2012; Soltepec, Tlax. 2011, 2014; Teacalco, Tlax. 2012; Tepatitlan, Jal. 2011, 2012; Terrenate, Tlax. 2F 2013; Tlalmanalco, Mex. 2014, 2015; V. of Guadiana, Dgo. 2014; Velasco, Tlax. 2012, 2014; Yanhuitlan, Oax. 2011.

Critical environments (29 environments with performance lower than 1 500 kg ha^{-1}): Atlangatepec, Tlax. 2011; Axapusco, Mex. 2014; Carbajal, Oax. 2012; Chalco, Mex. 2012; Cuyoaco, Pue. 2011; Fco. I. Madero, Dgo. 2012, 2014; The Calaveras, Mex. 2012, Nanacamipa, Tlax. 2013; Pabellon, Ags. 2011, 2012, 2014; Paramo, Chih. 2012; Roque, Gto. 2014; Sandovales, Ags. 2012, 2014; Sta. Lucia, Mex. 2015; Sinaxtla, Oax. 2011; Soltepec, Tlax. 2015; Terrenate, Tlax. 2011, 2012, 2014, 2015; V. of Guadiana, Dgo. 2011, 2012; Velasco, Tlax. 2013, 2015; Veloz, Tlax. 2013.

The greatest advantage of Ágata over the control varieties was in intermediate production environments, where there were generally severe incidences of stem rust, as the production condition was improved so that greater grain yield was expressed, the advantage of Ágata was reduced on the control varieties, among other causes, because in favorable environments there is usually a lower incidence of stem rust. In environments of low productivity, where drought conditions generally occurred, Ágata surpassed all varieties, but its advantage was lower, especially on Turquesa, which has been characterized by its good response under water conditions (Villaseñor *et al*., 2009).

Conclusions

Ágata is a new variety of oats with a high grain yield potential that is recommended for sowing in critical, intermediate and favorable production environments in the seasonal areas where oats are produced during the Summer in the states of Oaxaca, Puebla, Tlaxcala, Hidalgo, State of Mexico, Queretaro, Michoacan, Jalisco, Aguascalientes, Zacatecas, Durango and Chihuahua. It is suitable for use from early plantings to late dates, as for example in the High Valleys of Mexico, from the beginning of June to the end of July, in the first case for the production of grain and in the second for the production of groomed forage.

Acknowledgments

To INIFAP through the support provided through the project called: generation of technology to increase the productivity of the oat crop in the central region of Mexico.

Cited literature

Huerta, E. J. y Singh, R. P. 2000. Las royas del trigo. *In:* el trigo de temporal en México. Villaseñor-Mir, H. E. y Espitia- Rangel, E. (Eds.). Campo Experimental Valle de México (CEVAMWX). SAGAR-INIFAP-CIRCE. Estado de México. 231-251 pp.

Leyva, M. S. G.; Espitia, R. E.; Villaseñor, M. H. E. y Huerta, E. J. 2004. Pérdidas ocasionadas por *Puccinia graminis* f. sp. *avenae* Eriks. y Henn., causante de la roya del tallo en seis cultivares de avena en Valles Altos de México. Rev. Mex. Fitopatol. 22(2):166-171.

Mariscal; A. L. A.; Huerta, E. J.; Villaseñor, M. H. E.; Leyva, M. S. G.; Sandoval, I. J. S. y Benítez, R. I. 2011. Selección de genotipos de avena para la identificación de razas de roya del tallo. Rev. Mex. Cienc. Agríc. 2(4):593-600.

Prescott, J. M.; Burnett, P. A. and Saari, E. E. 1986. Enfermedades y plagas del trigo: una guía para su identificación en el campo. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT). El Batán, Estado de México. 148 p.

Roelfs, A. P.; Singh, R. P. y Saari, E. E. 1992. Las royas del trigo. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT). El Batán, Estado de México. 81 p.

SIAP. 2016. Servicio de Información y Estadística Agroalimentaria y Pesquera. SAGARPA. México, DF. www.siap.gob.mx.

Villaseñor, M. H. E. y Espitia, R. E. 2000. Características de las áreas productoras de trigo de temporal: problemática y condiciones de producción. *In:* Villaseñor, M. H. E. y Espitia, R. E. (Eds.). El trigo de temporal en México. Campo Experimental Valle de México (CEVAMEX). SAGAR-INIFAP. Chapingo, México. Libro técnico. 85-98 p.

Villaseñor, M. H. E.; Espitia, R. E.; Huerta, E. J.; Hortelano, S. R. R.; Martínez, C. E.; Rivas, V. P.; Martínez, T. G.; Rodríguez, C. M. E. y Ramírez, V. Y. 2015. El programa de mejoramiento genético de avena del CEVAMEX. *In*: segunda reunión estatal de investigación: contribuciones científicas y tecnológicas del Campo Experimental Valle de México a 30 años de la creación del INIFAP y retos ante el cambio climático. Memoria técnica núm. 2. 99-115 pp.

Villaseñor, M. H. E.; Espitia, R. E.; Huerta, E. J.; Osorio, A. L. y López, H. J. 2009. Turquesa, nueva variedad de avena para la producción de grano y forraje en México. Agric. Téc. México. 35(4):487-492.