Article

Productive potential of rice 'Lombardía FLAR 13', genotype of long and thin grain of the rice-growing area of Michoacán

Juan Carlos Álvarez-Hernández[1§]
Luis Mario Tapia-Vargas[2]
Leonardo Hernández-Aragón[3]
Leticia Tavitas-Fuentes[3]
Maricela Apaez-Barrios[4]

[1]Apatzingán Valley Experimental Field-INIFAP. Apatzingán-Cuatro Caminos highway km 17.5, Antúnez, Parácuaro, Michoacán, Mexico. ZC. 60781. [2]Uruapan Experimental Field-INIFAP. Av. Latinoamericana num. 1101, col. Revolution, Uruapan, Michoacan, Mexico. ZC. 60150. (tapia.luismario@inifap.gob.mx). [3]Zacatepec Experimental Field-INIFAP. Zacatepec-Galeana highway km 0.5, Zacatepec, Morelos, Mexico. ZC. 62780. (hernandez.leonardo@inifap.gob.mx; tavitas.leticia@inifap.gob.mx). [4]Faculty of Agricultural Sciences-UMSNH, Mariano Jiménez s/n, El Varillero neighborhood, Apatzingán, Michoacán, Mexico. ZC. 60160. (maricela.apaez@umich.mx).

[§]Corresponding author: alvarez.juan@inifap.gob.mx.

Abstract

In Mexico, it has been a challenge to meet the national demand for rice, which exceeds 850 000 tons per year, so in recent years imports have been resorted to. Given this, in order to counteract this situation, the development of technologies specific to production systems and the implementation of genetic improvement programs aimed at the generation of genotypes and their adaptation to the rice-growing areas of the country have been encouraged. Despite the efforts, there is still a lack of long and thin grain rice varieties that are of good industrial grain quality and competitive with imported rice, in addition to being preferred by the consumer. Consequently, in the rice-growing region of Michoacán, advanced rice lines were identified, where the Lombardía FLAR 13 genotype emerged. During the 2017 to 2020 cycles, this material was experimentally evaluated in comparison with the Milagro Filipino genotype in Lombardía, municipality of Gabriel Zamora, Michoacán. Morphological and productive variables were recorded. With the data obtained, in addition to the verification of the tests of normality and homogeneity of variances, they were analyzed with the t-student statistical test for independent samples. The results showed superiority of the Lombardía FLAR 13 genotype over the Milagro Filipino genotype, since in most of the morphological variables evaluated, it equaled and even exceeded in the productive variables, particularly in the latter, the yields were greater than 9 t ha^{-1}, it also showed productive stability during the evaluated cycles, so it is competitive with the conventional variety Milagro Filipino, which is established in the area.

Keywords: *Oriza sativa*, FLAR, Latin American fund for irrigated rice, rice genotypes.

Reception date: February 2022
Acceptance date: June 2022

Introduction

Rice (*Oriza sativa* L.), due to its food importance worldwide, is one of the most appreciated cereals, contains a large amount of energy, provides 27% of the food supply, compared to wheat which supplies 19% and corn only 5%; regarding proteins, every 100 g of rice contains approximately 6.8 g of protein; 1.2 mg of iron; 0.5 mg of zinc and 0.6 g of fiber; likewise, it is an important source of thiamine, riboflavin and niacin (Tavitas *et al*., 2016a). Consequently, globally, rice is produced in 113 countries concentrated in the vast regions of Africa, America, Asia, Europe and Oceania. According to FAO, in a 10-year period (2010 to 2019), world production increased by 8.13%. Of this trend, the countries concentrated in Asia produced 90% of the total production, equivalent to 627 452 833 t in 2010 and it reached 677 276 789 t in 2019. On the other hand, Africa and America in the decade of the record, participated with 4% and 5% in world production, respectively, maintaining the production volume in the last year 2019, the 38 771 392 t and 35 325 593 t, respectively. Europe and Oceania, even with a significant tonnage of production and participation, this was less than 1% in the period (FAOSTAT, 2021).

In Mexico, according to SIAP-SADER (2020), this species participated with 0.8% of the national grain production, and the annual *per capita* consumption was 9 kg. Thus, rice is one of the four staple crops, after corn, wheat and beans, which is part of the Mexican diet. Therefore, the national demand for this cereal has been increasing, estimated at one million tons per year, however, since recent years, national production has improved little, with the consequence of depending on the massive import of rice (Osuna *et al*., 2000; Chávez-Murillo *et al*., 2011). Given these circumstances, it is a great challenge for Mexico and for the producers themselves to supply the national demand. Proof of this, in the last five years, the national production has little transcended, going from 254 043 t in 2016 to 295 338 t in 2020 (SIAP-SADER, 2021). Therefore, to balance the demand and supply of this grain and in order to be in competitive possibilities against other rice-producing countries, in addition to the technologies developed and implemented, it is necessary to simultaneously promote the development of production systems according to current conditions and boost support for the production and commercialization of the grain, aimed at achieving greater profitability of the crop as a whole (Tavitas *et al*., 2016b).

It is important to specify that two production systems are used in the country, one based on the supply of irrigation and the other subject to supply with rainfall. That of irrigation system is located mainly in the Pacific region, it consists of the states of Nayarit, Jalisco, Colima, Michoacán, Guerrero, State of Mexico, Morelos and Oaxaca. That of the rainfed system is located in the Southeast, it includes the states of Tamaulipas, Veracruz, Tabasco, Chiapas, Campeche and Quintana Roo (Hernández and Tavitas, 2005). Both pests and diseases constitute the main limitations in the crop, 43 diseases are reported and of the 70 recognized species, only 20 insect pests are considered the most important (Pathak and Khan, 1994). Therefore, in recent years, some agricultural practices in the technological package have been modified, together with the release of varieties with great yield potential (Salcedo and Barrios, 2012; Álvarez *et al*., 2016; Barrios *et al*., 2016; Hernández *et al*., 2019). This has resulted in yields greater than 9 t ha^{-1}.

Particularly in the state of Michoacán, rice cultivation represents an important economic activity for producers in the municipalities of Buenavista, Parácuaro, Apatzingán, Gabriel Zamora and Nuevo Urecho, consequently, the evaluations of advanced rice lines for the Apatzingán Valley have been oriented to the determination of yield stability parameters (Álvarez *et al*., 2018). Under this perspective; recently, the rice genotype called Lombardía FLAR 13 has been a rice material adapted to the soil and climatic conditions of the region, therefore it was monitored in order to determine its productive capacity and stability. Based on the above, the objective was to evaluate the advanced rice line Lombardía FLAR 13, compared to the conventional material in different production cycles, in the Apatzingán Valley, Michoacán. Under this precept, the hypothesis raised was the genotype of long and thin grain rice has the capacity to develop and produce properly in the climatic conditions of the rice-growing area of Michoacán.

Materials and methods

Soil, climatic and landscape characteristics of the rice-growing area

In the rice-growing region of Michoacán, soils are identified by having high water retention capacity, high clay contents and, due to plain condition, are easily floodable, although they can differ in color and depth, these soils are the ones with the highest grain yield and correspond to Vertisols pelic (FAO, 2008). Also, in the Apatzingán Valley, the BS_1 climate is frequent, corresponding to the group of dry climates, the least dry of the BS, very warm, with average annual temperature >22 °C, that of the coldest month >18 °C, summer rainfall regime at least 10 times more rainfall in the wettest month of the hottest half of the year than in the driest, with a percentage of winter rainfall <5% of the annual rainfall, with little oscillation, Köppen, modified by García (2004); INEGI (2016). Regarding the type of vegetation, it is represented by the primary vegetative types of low deciduous rainforest, secondary stages of natural succession (different degrees of regeneration after elimination), of shrubby size of 4 to 8 m in height and arboreal size of 8 to 12 m in height and in higher areas, small extensions of oak and pine forests (Andres *et al*., 1994; García and Linares, 2012).

Planning of productive stability experiments

Through promising materials obtained in national compact trials and through the establishment of validation plots under irrigation and rainfed conditions, advanced experimental lines of long and thin grain rice were selected, during the autumn-winter cycles of the year 2013 to the year 2016, a line identified as Lombardía FLAR 13 was observed, which stood out agronomically for the region, it originated from an advanced line in generation F6 from a triple cross with characteristics of long and thin grain. Therefore, the Lombardía FLAR 13 line underwent a validation process, which formally began from 2017 to 2020, following up through field experiments, compared to the Milagro Filipino variety. Within the properties of cooperating producers of the Lombardía ejido, municipality of Gabriel Zamora, Michoacán, the experimental validation plots were established annually, whose sowing dates were from June 5, for a period of approximately four months to harvest each year. The average annual climate data of precipitation, maximum and minimum temperatures, and evaporation that occurred during the periods 2017 to 2020 are shown in (Table 1).

Table 1. Climatic variation during experimental trials.

Climatic variables	Average monthly value (June, July, August, September, October)			
	2017	2018	2019	2020
Maximum temperature(°C)	37	38.1	39	38.2
Minimum temperature (°C)	18.2	18.9	17.3	17.5
Precipitation (mm)	136.62	114.74	95	102.74
Evaporation (mm)	5.59	5.77	6.52	6.09

Department of Hydrometry, Irrigation District 097, CONAGUA, Mexico.

The preparation of the soil consisted of basic mechanized tasks of fallow, harrowing, leveling and formation of ridges at 2.1 m. Immediately the seed was dispersed manually by broadcasting, at a density of 80 kg ha^{-1} and 'a pass' with tractor and implement conditioned only with the rudders was carried out, marking small furrows 0.3 m apart (Coria *et al*., 2017). Management consisted of basic tasks (Hernández *et al*., 2013), of application of sprout irrigation, later supplemental irrigations with intervals of between 5 and 8 days, the control of weeds was done with selective pre- and post-emergent herbicides (Esqueda and Tosquy, 2014), the fertilization was done in two stages (approximately at 20 days of emergency and in the stage of 'booting' or formation of floral primordium) (Tapia *et al*., 2016) and application of systemic fungicides (Hernández *et al*., 2018).

The treatments used were the genotypes Lombardía FLAR 13 (LF 13) and Milagro Filipino (MF), under experimental design of independent plots, each treatment made up of four 'border strips' of 2.1 m x 40 m, giving an area of 336 m^2 per treatment. The data record per experimental unit was made up of four blocks (based on each border strip of the four considered by treatment), the number of plants considered by treatment was 20 for morphological and phenological aspects and for the productivity of one square meter for each border strip.

The variables evaluated were plant height (it was measured from the soil base to the point of union between the panicle and the flag leaf with a tape measure), the number of tillers (suckers), the number of spikes and grains per spikes, the length of spikes (the length of the main spike was measured with a tape measure), grain yield at the time of harvest, postharvest grain yield, and hectoliter weight (these were recorded with a digital scale). The difference between the grain yield variables is due to the fact that the moisture content of the grains is higher at the time of harvest.

The data were verified by tests of normality and homogeneity of variances prior to statistical analysis, and then compared by the t-student statistical test for independent samples, using the statistical package Past 4.06, open access software developed by the Natural History Museum, University of Oslo (Hammer, 2021). Also, a Pearson correlation test (r, p= 0.05) was run on most of the variables against the variables post-cut grain yield.

Results

The average values of agronomic behavior in the different morphological variables and respective years are shown concentrated in Table 2. In principle, the results of the statistical analysis for the variable plant height showed differences only in the study cycles (*p*= 0.00008, 0.03, 0.07, 0.5), 2020 did not show differences. As can be seen in Table 2, the Lombardía FLAR 13 treatment surpassed the Milagro Filipino treatment, on average by 4 cm, although it is important to note that the compact condition in rice materials is desirable (Table 2).

Regarding the number of 'tillers' per plant, the statistical analysis showed significant differences only in the 2019 and 2020 cycles (Table 2). The Milagro Filipino treatment was exceeded by 1.5 units by the Lombardía FLAR 13 treatment. Also, despite not showing significant differences in the 2017 and 2018 cycles, the Lombardía FLAR 13 treatment presented the highest number of tillers. Quantitatively, the Lombardía FLAR 13 treatment showed values, in most cycles, slightly above 11 'tillers' per plant, while the Milagro Filipino treatment was closer to 10 tillers per plant (Table 2).

Table 2. Behavior of morphological variables in the Milagro Filipino and Lombardía FLAR 13 treatments in different agricultural cycles. Apatzingán Valley.

Cycles	Treatments	Plant height	Number of tillers	Number of spikes	Spike length	Grains per spike
2017	MF	69.6 ±1.4 b	10.4 ±0.5 a	10.7 ±0.6 b	25.7 ±1 a	183.6 ±12.8 b
	LF 13	74.2 ±1.6 a	11.4 ±0.6 a	12 ±0.5 a	25.9 ±1 a	212 ±20.9 a
2018	MF	71 ±3.4 b	10.4 ±0.7 a	10.2 ±0.7 b	25.9 ±1 a	186.1 ±24.3 a
	LF 13	75.4 ±2.5 a	10.8 ±0.6 a	11.4 ±0.6 a	26.6 ±1.2 a	211.9 ±24.6 a
2019	MF	73.3 ±2.2 b	10.1 ±0.8 b	10.3 ±0.7 a	25.8 ±1.1 a	184.8 ±18.2 a
	LF 13	76.2 ±2.3 a	11.6 ±1.1 a	10.9 ±0.6 a	26.4 ±1.5 a	203.6 ±23.8 a
2020	MF	73.8 ±2.4 a	10.2 ±0.8 b	10.4 ±0.3 b	25.8 ±1.2 a	194.6 ±25 a
	LF 13	74.8 ±3 a	11.5 ±0.6 a	12.2 ±0.5 a	26 ±1.3 a	206.1 ±26.9 a

Means ± amplitude of the confidence interval (95%) with different letters indicates statistical differences according to the t-student test ($p < 0.05$); n= 20.

For the number of spikes per plant, the analysis showed statistical differences in most cycles (*p*= 0.003, 0.01, 0.2, 0.0000006), except for 2019, which was statistically equal. As can be seen in Table 2, the Lombardía FLAR 13 treatment had on average two more spikes than the Milagro Filipino treatment (Table 2). For its part, in the variable length of spikes, the statistical analysis found no difference, and the length was 26 cm on average, for both treatments (Table 2).

A behavior very similar to the previous variable was shown by the number of grains per spike, where only the 2017 cycle showed significant differences. No differences were detected in subsequent cycles. Despite this, it is important to highlight the trend observed in this variable, since both the Milagro Filipino treatment and the Lombardía FLAR 13 treatment showed stable values in the four years and whose difference between the two fluctuated only in approximately 20 seeds, with the Milagro Filipino treatment being lower (Table 2).

For the variable yield per area at the time of harvest, the statistical analysis detected significant differences in the four evaluation cycles (Figure 1). The Lombardía FLAR 13 treatment exceeded the Milagro Filipino treatment by more than 333 g m^{-2} on average of the evaluation cycles. Thus, the Lombardía FLAR 13 treatment showed values higher than 1 250 g m^{-2} average in the evaluation cycles (Figure 1).

Subsequently, the statistical analysis applied to the yield per square meter after harvest found significant statistical differences (Figure 1). As can be seen, the Lombardía FLAR 13 treatment continued to be superior to the Milagro Filipino treatment, since the time invested in the drying of the moisture in grain, it maintained a trend similar to the variable yield per square meter at the cut, so the Lombardía FLAR 13 treatment stood out with values between 1 085 to 1 118 g m^{-2}, and between 260 g m^{-2} above the Milagro Filipino treatment (Figure 1).

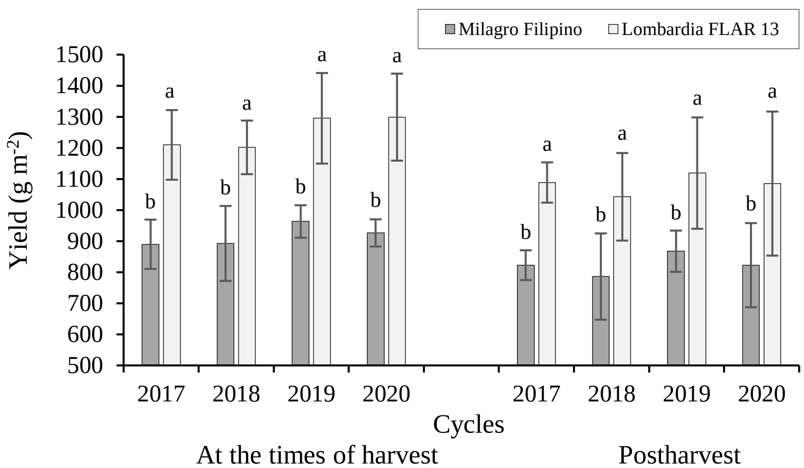

Figure 1. Behavior of the variables grain yield at the time and after harvest in the Milagro Filipino and Lombardía FLAR 13 treatments in different agricultural cycles. Means ± amplitude of the confidence interval (95%) with different letters indicates statistical differences according to the t-student test (p< 0.05); n= 20.

The variable hectoliter weight, only in the 2017 and 2019 evaluation cycles, there were statistical differences and in the years 2018 and 2020, the treatments were not significant. As can be seen, the values were between 20 and 23 g for the Milagro Filipino treatment. In contrast, for the Lombardía FLAR 13 treatment, the hectoliter weight reached 28 g on average for the four years of study (Figure 2).

In addition, to determine the relationship between the variable grain yield and the rest of the variables that are part of the components of the yield, the correlation analysis (r) obtained some positive correlations in the two genotypes during the agricultural cycles (Table 3). As can be seen, the variables number of tillers and grains per spike are the variables most related to the variable grain yield. The rest of the variables show some positive relationships, but they were not as constant (Table 3).

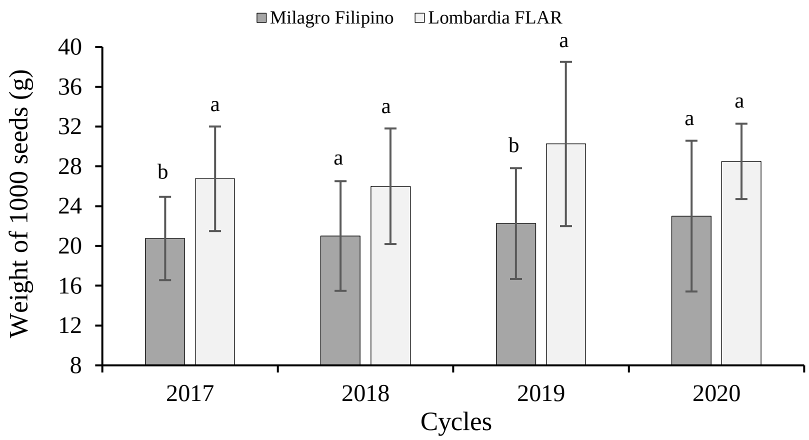

Figure 2. Behavior of the variable hectoliter weight in the Milagro Filipino and Lombardía FLAR 13 treatments in different agricultural cycles. Means ± amplitude of the confidence interval (95%) with different letters indicate statistical differences according to the t-student test ($p < 0.05$); n= 20.

Table 3. Pearson correlation coefficient (r, $p < 0.05$) between the variable postharvest grain yield and the agronomic variables of the yield components, in Milagro Filipino and Lombardía FLAR 13 treatments under different agricultural cycles. Apatzingán Valley, Michoacán.

Variables	Postharvest yield per area (*r*)							
	2017		2018		2019		2020	
	MF	LF 13	MF	LF 13	MF	LF 13	MF	LF 13
Plant height	-0.25	0.69	0.02	-0.11	-0.9	0.63	-0.55	-0.33
Number of tillers	0.14	-0.2	0.54	-0.74	0.41	0.59	0.63	-0.86
Number of spikes	-0.78	0.21	-0.77	0.42	-0.52	0.65	-0.06	-0.99
Spike length	-0.81	0.7	0.55	-0.16	0.98	-0.28	-0.31	-0.13
Grains per spike	0.35	0.38	0.4	-0.18	0.57	0.28	-0.83	0.2
Weight of 1000 seeds	-0.41	0.40	-0.81	0.98	-0.39	-0.41	0.31	-0.08

Discussion

Mexico produces two types of grains for consumption, the coarse grain that covers 75% and the thin grain that covers 25%, the latter depends on the import in almost 100% (Barrios *et al*., 2016). Given this, the recent release of the varieties known as INIFLAR R and INIFLAR RT (SNICS, 2021), both long and thin grain with high yield potential, resistant to the endemic rice burning disease *Pyricularia oryzae* or *Magnaporthe grisea* and other diseases, which are part of the collection of alternative materials to the Milagro Filipino variety; in addition, they compete with imported long and thin grain rice (Hernández *et al*., 2015).

Meanwhile, the Pacifico FL15 and Golfo FL16 varieties (SNICS, 2021), also recently released, both resistant to the planthopper-WLV (white leaf virus) complex and the endemic rice burning disease (*Pyricularia oryzae*= *Magnaporthe grisea*), and moderately resistant to the spotted grain disease caused by *Helminthosporium oryzae*. It is estimated that with these varieties producers can contribute with the thin long grain demanded by the population (Hernández *et al*., 2019).

Regarding the state of Michoacán, as a participant in national production, ranked fourth in established area in recent years and yields slightly higher than 8 t ha^{-1} (SIAP-SADER, 2021), a situation that has prompted to carry out experimental work on the behavior of advanced rice lines, giving rise to the Lombardía FLAR 13 genotype, which has characteristics that the consumer demands. In addition, given the situation that prevails in the overexploited variety Milagro Filipino, being predominant in rice-growing areas but which has lost its purity, whose yields are lower than those of the group of long and thin grain materials (García *et al*., 2011).

This situation was verified in the present study, since the development of the tillers and number of spikes, there was a difference of one tiller and two spikes between the Lombardía FLAR 13 genotype over the Milagro Filipino genotype, respectively (Table 1). In grain yield at harvest, the Lombardía FLAR 13 genotype exceeded the Milagro Filipino genotype by more than 333 g m^{-2} on average in the years of evaluation, which represents an increase of three tonnes per hectare (Figure 1). This response can be attributed to the ability to adapt to the environmental conditions of the region, which allows it to produce a greater number of tillers and in turn a greater number of spikes, but also, greater weight of the grains.

Therefore, this material is of high potential yield, does not lodge or shells and is tolerant to diseases, since these were not present in the evaluation cycles. In addition, due to the results, it was stable in the climatic condition of the rice-growing area of Michoacán. In terms of industrial quality, the long, thin grain it produces was acceptable, making it competitive with imported rice from Thailand and Vietnam (Tolentino, 2014).

On the other hand, the technology used in the cultivation of rice in Michoacán improved, the sowing is direct in furrows and supplemental irrigations. In this aspect, unlike other species, water is essential for the rice plant to complete its essential functions and reduce competition from weeds and other antagonistic plants. An important aspect of the Lombardía FLAR 13 genotype, like the new varieties released, is that they do not require continuous flooding, which allows efficiency and better use of the resource.

In the production system, direct sowing in furrows and supplemental irrigations works significantly. While the heat stress experienced by the plant is a function of the air temperature, and the genetic and agronomic factors that determine the evaporative cooling potential of the plant (López-Hernández, 2018). Faced with this situation, the management of water in this crop must gradually transcend new schemes that respond to the imminent climate change.

Conclusions

The Lombardía FLAR 13 genotype showed productive stability in the environmental conditions of the Apatzingán Valley, it is also competitive with the conventional variety Milagro Filipino, which is established in the area, since, in most of the morphological variables evaluated, it equaled and even exceeded in the productive variables. Lombardía FLAR 13 expressed yields greater than 9 t ha^{-1}, is early, resistant to lodging and of good industrial quality, which gives certainty to its establishment on a larger scale.

Acknowledgements

Thanks to the National Institute of Forestry, Agricultural and Livestock Research for the support granted and the facilitations provided to carry out this research.

Cited literature

Andrés, A. J.; Arteaga, L. G.; Blancarte, D. M.; Calderón, A. J. H.; López, P. V.; Rivera, M. S. y Romero, P. J.; Santos, C. C. 1994. La producción agropecuaria de la región Valle de Tepalcatepec Michoacán. 1ra. Ed. Universidad Autónoma de Chapingo. 10-55 pp.

Álvarez, H. J. C.; Tapia, V. L. M. y Tavitas, F. L. 2016. Iniflar R: nueva variedad de arroz de grano largo delgado para regiones productoras de riego en México. Rev. Mex. Cienc. Agríc. Pub. Esp. 17:3649-3654.

Álvarez, H. J. C.; Tapia, V. L. M. and Hernandez, P. A. 2018. New genotypes of long and thin grain rice and technology for production in Mexico: Michoacan state as an example. *In*: Tadele, Z. (Ed). Grasses as food and feed. 1ra. Ed. INTECHOPEN. United Kingdom. 3-23 pp.

Barrios, G. E. J.; Hernández, A. L.; Tavitas, F. L.; Ortega, A. R.; Jiménez, C. J. A.; Tapia, L. M.; Morelos, V. H.; Hernández, P. A.; Esqueda, E. A. V. y Uresti, D. D. 2016. INIFLAR RT, variedad de arroz de grano delgado para México. Rev. Mex. Cienc. Agríc. 7(4):969-976.

Chávez, M. C. E.; Wang, Y. J.; Quintero, G. A. G. and Bello, Pérez, L. A. 2011. Physicochemical textural and nutritional characterization of Mexican rice cultivars. Cereal Chemistry. 88(3):245-252.

Coria, A. V. M.; Álvarez, H. J. C.; Venegas, G. E. y Vidales, F. I. 2017. Agenda Técnica Agrícola de Michoacán. SAGARPA. COFUPRO. INIFAP. México. 180-187 pp.

Esqueda, E. V. A. and Tosquy, V. O. H. 2014. Validation of cyhalofop butyl clomazone to control *Echinochloa colona* (L.) Link in rainfed rice. Mexican journal of agricultural sciences. 5(5):741-751.

FAO. 2008. Food and Agriculture Organization of the United Nations. Base referencia mundial del recurso suelo. Un marco conceptual para la clasificación, correlación y comunicación internacional. Versión en español. Roma, Italia. 96-98 pp. ISBN 978-92-5-305511-1.

FAOSTAT. 2021. Estadísticas de la producción mundial de arroz. Datos disponibles en internet. http://www.fao.org/faostat/es/#data/QC.

García, A. E. 2004. Modificaciones al sistema de clasificación climática de Köppen, para adaptarlo a las condiciones de la República Mexicana. 5ta. Ed. UNAM. México. 62-74 pp. ISBN: 970-32-1010-4.

García, A. J. L.; Hernández, A. L. y Tavitas, F. L. 2011. El Silverio: nueva variedad de arroz para el trópico mexicano. Rev. Mex. Cienc. Agríc. 2(4):607-612.

García, R. I. y Linares, L. A. 2012. Árboles y arbustos de la cuenca del rio Tepalcatepec (Michoacán y Jalisco, México) para uso urbano. El Colegio de Michoacán AC. e Instituto Politécnico Nacional. 1ra. Ed. México. 15-37 pp. ISBN: 978-607-8257-07-2.

Hammer, O. 2021. PAST V. 3.2. Reference manual. Natural History Museum, University of Oslo. 47-105 pp.

Hernández A. L. y Tabitas, F. L. 2005. Plan nacional de investigación y apoyos a la transferencia de tecnología en la cadena agroalimentaria arroz. SAGARPA-INIFAP-CONACYT. Campo Experimental Zacatepec. Publicación especial núm. 42. 1-66 pp.

Hernández, P. A.; Tapia, V. L. M.; Larios, G. A.; Vidales, F. I. y Rico, P. H. R. 2013. Tecnología para la producción de arroz en el trópico seco de Michoacán. Guía técnica núm. 1. INIFAP-CIRPAC. Campo Experimental Valle de Apatzingán. 10-43 pp. ISBN: 978-607-37-0071-9.

Hernández, A. L.; Tavitas, F. L. y Alberto, P. 2015. Paquetes Tecnológicos para el cultivo de arroz en México. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Centro de Investigación Regional Pacifico Sur. Campo Experimental “Zacatepec”. Zacatepec, Morelos, México. Folleto técnico núm. 87. 1-29 pp.

Hernández, A. L.; Tavitas, F. L. y Barrios, G. E. J. 2018. Tecnologías y sistemas de producción para las variedades de arroz de grano largo delgado, INIFLAR R, Pacífico FL 15 y Golfo FL 16. Folleto para productores núm. 71. SAGARPA-INIFAP-CIRPAS. Campo Experimental Zacatepec. Zacatepec, Morelos, México. 25-45 pp.

Hernández, A. L.; Tavitas, F. L.; Álvarez, H. J. C.; Tapia, V. L.; Ortega, A. R.; Esqueda, E. V. y Jiménez, C. J. A. 2019. Pacífico FL 15 y Golfo FL 16, variedades multiambientales de arroz con grano extralargo para México. Rev. Mex. Cienc. Agríc. 10(1):23-34.

INEGI. 2016. Anuario estadístico y geográfico de Michoacán de Ocampo 2016. Instituto Nacional de Estadística y Geografía. 1ra. Ed. México. 18-45 pp.

López, H. M. B.; López, C. C.; Kohashi, S. J.; Miranda, C. S.; Barrios, G. E. J. y Martínez, R. C. G. 2018. Drought and heat tolerance in rice (*Oryza sativa*). Ecosistemas y Recursos Agropecuarios. 5(15):373-385. Doi: https://doi.org/10.19136/era.a5n15.1558.

Osuna, C. F. J.; Hernández, A. L.; Salcedo, A. J.; Tavitas, F. L. y Gutiérrez, D. L. J. 2000. Manual para la producción de arroz en la región central de México. SAGAR. INIFAP. CIRCE. Campo Experimental Zacatepec. Libro técnico núm. 1. 1-5 pp.

Pathak, M. D. and Khan, Z. R. 1994. Insect pest of rice. International Rice Research Institute. Manila, Philippines. 1-3 pp. ISBN 971-22-0028-0.

Salcedo, A. J. y Barrios, G. E. J. 2012. Morelos A2010: nueva variedad de arroz para siembra directa para el centro de México. Rev. Mex. Cienc. Agríc. 3(7):1453-1458.

SIAP. 2020. Servicio de Información Agroalimentaria y Pesquera. Panorama Agroalimentario. Secretaria de Agricultura y Desarrollo Rural. México. 38-39 pp.

SIAP-SADER. 2021. Estadísticas de la producción nacional de papaya. Datos disponibles en internet. http://infosiap.siap.gob.mx:8080/agricola_siap_gobmx/ResumenProducto.do.

SNICS. 2021. Servicio Nacional de Inspección y Certificación de Semillas. Catálogo Nacional de Variedades de Semillas. https://datastudio.google.com/u/0/reporting/5b7206ba-e190-48fe-9696-73523bfccf58/page/itBWB.

Tapia, V. L. M.; Hernández, P. A. y Álvarez, H. J. C. 2016. Nutrición y manejo de fertilizantes. *En*: Hernández-Aragón, L. y Tavitas-Fuentes L. (Ed). El arroz en México. Libro técnico num. 14. INIFAP. CIRPAS. Campo Experimental Zacatepec. Zacatepec, Morelos, México. 309-331 pp.

Tavitas, F. L.; Valle, V. M. y Martinez, M. E. 2016a. Calidad del grano. En: Hernández-Aragón, L. y Tavitas-Fuentes L. (Ed). El arroz en México. Libro técnico núm. 14. INIFAP. CIRPAS. Campo Experimental Zacatepec. Zacatepec, Morelos, México. 393-440 pp.

Tavitas, F. L.; Hernandez, A. L. y Reyna, T. T. J. 2016b. Producción y postproducción de arroz (*Oriza sativa* L.) en México y la importancia en la seguridad alimentaria. En: Reyna, T. T. J.; Vega, L. M. y Ortuño, G. M. (Ed). Producción, postproducción y agrotecnias de semillas, hortalizas y frutas. Coadyuvantes en la seguridad alimentaria en México y Cuba. Instituto de Geografía UNAM. 66-90 pp. Doi: http://dx.doi.org/10.14350/gd.02.

Tolentino, M. J. M. 2014. The rice production of the state of Morelos under the approach SIAL. Rev. Estud. Soci. 22(44):38-61. ISSN 0188-4557.