Article

Production stability of advanced rice lines long thin grain in Michoacán Mexico

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Abstract

In Mexico, long and thin rice is the most consumed, so its supply has depended mainly on imports. Consequently, the Mexican Rice Council handed INIFAP the elite lines that generated the Latin American Rice Irrigation Fund (FLAR) for the evaluation and selection of materials. In order to validate advanced lines of long and thin grain rice compared to conventional material under the conditions of the Michoacán production area, experimental works were developed in different cycles: autumn-winter 2014-2015 (trial 1), spring summer from years 2015 (trial 2), 2016 (trial 3) and 2017 (trial 4) and different genotypes: trial 1) INIFLAR RT, FL05601, “Milagro Filipino”; test 2) FL06747, FL08224, INIFLA R, INIFLAR RT, Ivory, Lombardy, “Milagro Filipino”; essay 3) Lombardy, FL08224, “Milagro Filipino”; and essay 4) Ivory, Lombardy “Milagro Filipino 2. The data recorded varied in each trial, but phenological and productive aspects were included, including yield. Analysis of variance and comparison of means were performed. In trial 1, treatments exceeded the regional average, between 8,000 and 8,500 kg ha-1. In trial 2, the treatments FL06747, INIFLAR R and Lombardy stood out significantly in performance. Also, the flowering and maturity of grain, appeared early compared to “Milagro Filipino”. In trials 3 and 4, the Lombardy treatment showed higher yields. It is concluded that the advanced lines presented capacity to adapt to the production area of Michoacán. These materials were superior to the conventional material, since they showed consistency in each trial.

Keywords: *Oriza sativa*, elite lines, genetic materials, paddy rice, rice technologies.

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Introduction

Because of its large amount of energy and protein, rice is one of the most valued cereals in the world, since it provides 20% of the food energy supply. Being an important part of the diet of the Mexican population, the per capita consumption is from 4.7 to 6.9 kg, therefore, the national demand for this cereal increased, estimated at one million tons per year; however, from 2001 to date, the national production decreased to 254 000 annual tons produced in 41 000 ha, and distributed in 13 states (SIAP-SAGARPA, 2016).

This situation has led to the dismantling of the rice chain, which is why imports are used. In addition, these imports tend to grow up to 85% of national consumption (Ireta *et al*., 2011) mainly of long and thin grain materials.

Due to this situation, INIFAP implemented a genetic improvement project with materials from the Latin American Irrigation Rice Fund (FLAR) to obtain varieties with this type of grain. It should be noted that the studies focus on the type of grain that determines consumer preference and that also meets the quality of flour, food and nutrition (Barrios *et al*., 2016a), as well as the characterization of phenotypic diversity through Agro-morphological traits (Bajracharya *et al*., 2006).

Despite the efforts, there are still not enough varieties of long-grain rice adapted to the different agro-ecological conditions (Barrios *et al*., 2016a); however, in some regions advanced experimental lines have been selected, including, this has allowed the release of long and thin grain materials such as line FL05392-3P-12-2P-2P-M, registered as INIFLAR R (Álvarez *et al*., 2016) and the line FL04621-2P-1-3P-3P-M, registered as INIFLAR RT (Barrios *et al*., 2016b), who come to be an alternative in substitution to the variety “Milagro Filipino” that has been planted intensively and extensively, despite the remarkable loss of its purity (García *et al*., 2011).

The evaluations in advanced rice lines have been oriented to the determination of yield stability parameters, although their main execution has been in temporary conditions (Orona *et al*., 2013); However, due to the increase in climatic instability, these materials must undergo the production of lines with tolerance to abiotic stresses, mainly at low temperatures (Díaz *et al*., 2017a), in view of this, the effects of climate change, implementation of new technologies aimed at increasing yields per cultivated area, justify research in obtaining new rice materials, as suggested by Fu and Yang (2012), who report super varieties of rice released with high yields between 12 and 21 t ha^{-1}, however there are still deficient production schemes such as Cuba, which include technological indiscipline and non-compliance with good agricultural practices, which limits yields, since they are reported below 7 t ha^{-1} (Ruiz *et al*., 2016).

Consequently, it is important to follow up advanced materials, in order to increase the supply and availability of seed. Since Michoacán participates with 11.6% of the national production, the advances in the evaluations of these lines have allowed to select promising materials in substitution of the conventional variety. Based on the above, the objective was to evaluateadvanced lines of long and thin grain rice compared with conventional material in different production cycles and under the environmental conditions of the production area of Michoacán, Mexico.

Materials and methods

Through the selection of promissory materials obtained from national compact trials that have been carried out in the different rice regions of Mexico and through the establishment of validation plots under irrigation conditions, different long and thin grain materials were evaluated compared with the conventional material "Milagro Filipino", planting dates were within those recommended for the two production cycles (Hernández *et al*., 2016), in autumn winter of the year 2014-2015 (trial 1), spring summer of the year 2015 (trial 2), 2016 (trial 3) and 2017 (trial 4), in the municipalities of Paracuaro and Nuevo Urecho Michoacán, Mexico. In the study sites, the climate corresponds to the group of dry climates (García, 1988) and the soil unit corresponds to the pelic vertisols (FAO-UNESCO, 1991).

In the different production cycles, the evaluations were made up of the genotypes shown in Table 1. In trial 1, the genotypes INIFLAR RT, FL05601 and Milagro Filipino were evaluated; in trial 2 the genotypes FL06747, FL08224, INIFLA R, INIFLAR RT, Ivory, Lombardy and Milagro Filipino were evaluated, in trial 3 the Lombardy, FL08224 and Milagro Filipino genotypes were evaluated and in trial 4 the Ivory genotypes were evaluated, Lombardy and Milagro Filipino.

Table 1. Experimental rice materials evaluated and with potential for adoption in Michoacán, Mexico.

Origin	Genotype	Identification
VF (nursery FLAR)-2007 (year of release)	FL06747-4P-10-5P-3P-M	FL06747
VF-2009	FL08224-3P-2-1P-2P-M	FL08224
VF-2007	FL05601-6P-2-2P-2P-M	FL05601
VF-2006	FL05392-3P-12-2P-2P-M	INIFLAR R
VF-2005	FL04621-2P-1-3P-3P-M	INIFLAR RT
VF-2005	Ivory FLAR 13 (FL04867)	Ivory
Santa Rosa, Colombia	Lombardy FLAR 13 (FL04952)	Lombardy
IRRI from Philippines	IR8-288-3	Milagro Filipino

In general, the preparation of the soil of the experimental plots consisted of basic mechanized work of fallowing, tracking and leveling. In addition, small furrows of 0.2 m were marked between each other, and the sowing of seed was done directly to "chorrillo", under a density of 80 kg of seed per ha. The agronomic management consisted of basic tasks, mainly irrigation of relief with intervals between 5 and 8 days depending on the availability of water, as the main problem the control of weeds was made with selective pre- and postemergent herbicides (Esqueda and Tosquy, 2014), fertilization in two stages (approximately 20 days of emergency and "embuche") and application of fungicides. The experimental design used was randomized complete blocks; the size for each experimental plot was approximately 200 m^2 and the experimental unit was formed by four blocks of 1 linear meter for productivity and twenty plants for phenological aspects.

The data recorded were variable in each trial, for trial 1, plant height, weight of 1 000 seeds, number of ears per panicle, spike length and "pellet" yield was recorded. plant, spike length, number of spikes per panicle, number of tillers, weight of 1 000 seeds and yield of pellets, in addition appearance of phenological events in seed maturity, this was registered once more than 50% of the plants that presented it; in tests 3 and 4 only plant height and pellet yield were recorded. The data obtained were analyzed with the statistical program SAS (2002), through analysis of variance and comparison of means by Tukey test (p= 0.05).

Results and discussion

Regarding the variables recorded in trial 1 (Table 2), the analysis of variance showed significant statistical differences only in the variables plant height and the number of spikes per panicle. Specifically, in the height the treatment denominated INIFLAR RT had higher height than the materials FL05601 and "Milagro Filipino", although the FL05661 treatment is statistically similar to both INIFLAR RT and Milagro Filipino, in the variable number of spikes per panicle it exceeds both of them. Regarding the variables weight of 1 000 seeds, length of spikes and yield, the analysis of variance, did not detect differences, and whose values were very close, even in yield (Table 2), since the treatments slightly exceeded the regional average that it is from 8 000 to 8 500 kg ha^{-1} (SIAP-SAGARPA, 2016).

Table 2. Comparison of means of rice material productivity variables in Paracuaro, Michoacán, trial 1, agricultural cycle 2014-2015.

Treatments	Height of plant (cm)	Weight of 1 000 seeds (g)	Spikes for "panicle"	Shank length (cm)	Performance (kg ha^{-1})
INIFLAR RT	71.1 a	25.99	11.5 b	25.1	8 000
FL05601	66.8 ab	26.02	17.2 a	23.3	8 800
Milagro Filipino	63 b	26	14 b	26.1	8 500
DMS	7.1	0.03	2.7	2.9	0 900
CV	9.3	25.1	8.8	6.5	14.7
Significance	*	ns	*	ns	ns

DMS= minimum significant difference; cv= coefficient of variation; ns= not significant; *= $p \leq 0.05$.

It is worth noting that trial 1 was carried out in the autumn winter cycle, and that it covered its sowing since the end of 2014 and developed in the first months of 2015 under the irrigation condition, so unlike the treatment FL05601, the material INIFLAR RT and "Milagro Filipino" present a similar behavior in the variables number of spikes per panicle and spike length, even in the yield.

It is important to point out that INFLAR RT is a material designed for its establishment in irrigated or temporary conditions (Barrios *et al*., 2016b), but it thrives better in the spring-summer cycle, since it is when the rainy season coincides; For its part, in the treatment "Milagro Filipino", its performance was normal due to its production capacity and establishment period, as well as its loss of purity and its mixture with other varieties when considered a selection (García *et al*., 2011) in the process of degeneration.

On the other hand, Table 3 shows the results obtained from the productive variables in trial 2. The analysis of variance showed highly significant differences in all the variables. In the case of the height of the plant and the length of the spike, treatments FL06747 and FL08224, statistically surpassed the INFLAR R and RT treatments, including the Ivory and Lombardy treatments, and together with the treatment “Milagro Filipino”. Likewise, this trend was similar in the variables number of spikes per “panicle”, number of “tillers” and weight of 1 000 seeds, only that, in this case, the treatment “Milagro Filipino” statistically compared its behavior with treatments FL06747 and FL08224.

In terms of performance, the highest were for the treatments FL06747, INIFLAR R and Lombardy; however, the rest of the treatments also showed an acceptable yield, since they surpassed the conventional variety (Table 3). As was the case in trial 1, trial 2 was also established under the conditions of the municipality of Paracuaro, Michoacán. These results corroborate the capacity of long and thin grain rice materials to adequately develop in the spring-summer productive cycle, moreover, they surpassed the “Milagro Filipino” treatment, observing that the characterizations of these materials give distinguishable elements that allow the propitious choice, and this is given through the phenotypic diversity through morphological traits (Bajracharya *et al*., 2006).

Table 3. Comparison of means of rice material productivity variables in Paracuaro, Michoacán, trial 2, agricultural year 2015.

Treatments	Height of plant (cm)	Length of spike (cm)	Spikes per “panicle”	Num. of “tillers”	Weight of 1 000 seeds (g)	Yield (kg ha^{-1})
FL06747	88.75 a	30 a	21.6 a	13.4 a	32.1 a	11 575 a
FL08224	83.95 a	28.5 ab	19.8 ab	11 ab	30.2 ab	9 850 ab
INIFLAR R	72.85 b	27.2 bc	15.2 c	9.2 b	25 bc	11 512 a
INIFLAR RT	69.85 b	24.9 cd	17.4 bc	10.8 b	23.7 c	9 050 b
Marfil	71.7 b	24.7 cd	17 bc	9.2 b	25 bc	9 737 ab
Lombardía	71.8 b	25 cd	18.8 ab	10.6 b	24.5 bc	10 200 ab
Milagro Filipino	67.95 b	23 d	19.4 ab	11.6 ab	28.5 abc	8 200 b
DMS	7.04	2.65	3.3	2.45	6.9	2 380
CV	9.89	7.43	8.92	11.31	10.12	10.33
Significance	***	***	***	***	**	**

DMS= minimum significant difference; CV= coefficient of variation; ns= not significant; ** = $p\leq$ 0.01; *** = $p\leq$ 0.0001.

Particularly in the variable plant height, it is an important factor to consider in the choice of genotypes, in this case the recorded heights fluctuated between 69 and 88 cm (Table 3). Díaz *et al*. (2017a) reported heights of 104 cm in advanced rice lines; however, this variable is associated with problems of “acame”, that is, that greater height is more likely the risk of plant falls. One quality of “Milagro Filipino” is precisely its height that is compact, so that there is almost no loss of performance due to lodging. Therefore, a characteristic that is sought of these materials of long and delegated grain is precisely that they present a compact height. On the other hand, the variable spike length, spikes per panicle and grain weight, even the number of “tillers” influence yield.

Specifically, the number of "tillers", Díaz *et al*. (2017a) report on average 12.48 "tillers" per plant in advanced rice lines, whose data coincide with those reported in this trial, which obtained fluctuating values between 9 and 13 "tillers" (Table 3), this variable is important, because it is part of the productive capacity of the study materials. Although the trends of values in the components guide a certain performance, this can vary as observed, the treatments FL06747, INIFLAR R and Lombardy presented the highest yields (Table 3) and not necessarily related to the weight of grain and the other components, so that other factors that influenced the performance response as pathogens could probably have been present (Hernández-Arenas *et al*., 2012), loss of grain or empty grains. Despite this, the returns are acceptable, and coincide with other reports (Fu and Yang, 2012; Barrios *et al*., 2016b; Lacerda and Nascente, 2016).

Also, the record of phenological events in time related to grain maturity was taken (Figure 1). As shown, flowering occurred at 74 and 76 days in most treatments, with the exception of INIFLAR RT and "Milagro Filipino" treatments that were later; and this behavior was reflected in the later events of maturity "lechoza", "mature" maturity and even in the maturity of harvest, since it was presented at 112 and 113 days. On the other hand, INIFLAR RT and "Milagro Filipino" treatments were presented at 123 and 132 days, respectively (Figure 1).

Faced with increasingly unstable climate changes, an important feature that is valued quantitatively and qualitatively is the precocity of the materials, which has to do with the advancement of the crops, but without losing performance or quality, as it was observed, the different stages of the maturity of the grain appeared more quickly in the materials of long and thin grain (Figure 1), a situation clearly differentiated in the treatment "Milagro Filipino". It is also important to point out that in addition to this characteristic, other aspects such as tolerance to abiotic stress (Díaz *et al*., 2017b) must be explored, and mutants with good behavior in conditions of low water supply must be identified (González and Martínez, 2016) and other problems of biotic origin (Hernández-Arenas *et al*., 2012).

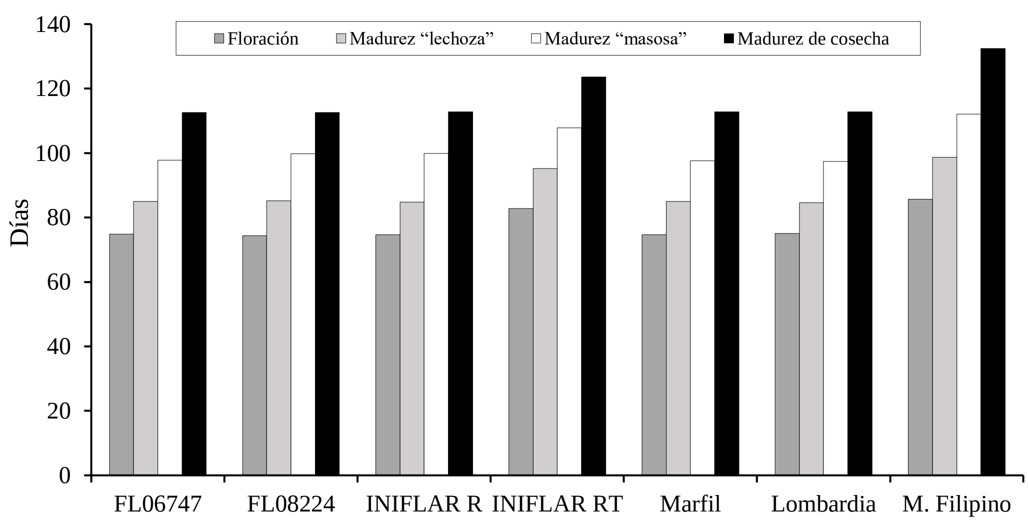

Figure 1. Physiological maturity of the grain in rice materials, Paracuaro, Michoacán, trial 2, agricultural year 2015.

On the other hand, Table 4 shows the results of the plant height and yield variables corresponding to trial 3. The analysis of variance only showed statistical differences in the performance variable, in which, the Lombardy treatment exceeded the treatments FL08224 and “Milagro Filipino”. As noted, without statistical differences, plant height had a similar performance trend, where treatments FL08224 and “Milagro Filipino” were inferior to the Lombardy treatment (Table 4). It should be remembered that this third trial was developed in the municipality of Nuevo Urecho, Michoacán and although the soil-climatic characteristics suggested in the corresponding section are similar, the performance of the FL08224 treatment is lower than the yield presented in test 2 with this same material, the interpretation for this purpose may be due to the productive systems from the point of view of seed quality and adaptability. This situation is likely to occur, since it should be noted that performance is a complex quantitative character that is largely influenced by environmental fluctuations (Orona *et al*., 2013).

Table 4. Comparison of means of the variables plant height and pellet yield in rice materials in Nuevo Urecho, Michoacán, trial 3, agricultural year 2016.

Treatments	Height of plant (cm)	Yield (kg ha^{-1})
Lombardy	71.08	12 003 a
FL08224	67.87	7 730 b
Milagro Filipino	68.91	8 255 b
DMS	5.31	3 154
CV	10.84	17.12
Significance	ns	**

DMS= minimum significant difference; CV= coefficient of variation; ns= not significant; $^{**}= p\leq 0.01$.

Similarly, the response of the plant height variables and the pellet yield in trial 4 are shown in Table 5. In this trial the analysis of variance revealed significant statistical differences in both variables. In the height of the plant, the Lombardy treatment presented the highest height, but statistically it was similar to the Ivory treatment and this in turn to the treatment “Milagro Filipino”, although its height was the lesser of both. In relation to the pellet yield, the Lombardy treatment statistically surpassed the Ivory and “Milagro Filipino” treatments, as it yielded more than 13 tons per hectare (Table 5). As it could be appreciated in the described trials, this behavior has been sold expressing, among the group of treatments of long and thin grain and “Milagro Filipino” because the stability of these materials has been manifested in terms of productivity.

The evaluations that have been made of experimental lines, particularly in Michoacan, have allowed the selection of materials adapted to the region, in addition to presenting characteristics that the consumer demands. It is important to note that in addition to the material “Lombardy” whose process and monitoring has been constant and stable, also the rice material called “Ivory” has exceeded expectations (Table 5), since its behavior in the field place it as another alternative of these new materials of long and thin grain. For its part “Milagro Filipino” is the predominant variety in the rice areas; however, the yields are lower than those of long and thin grain, besides that it is coarse grain and presents “white belly” (García *et al*., 2011), as it is known, the long and thin type rice is that of greater national consumption, so it is used to import it.

Table 5. Comparison of means of the variables plant height and pellet yield in rice materials in Nuevo Urecho, Michoacán, trial 4, agricultural year 2017.

Treatments	Height of plant (cm)	Yield (kg ha^{-1})
Ivory	72.05 ab	9 488 b
Lombardy	75.45 a	13 688 a
Milagro Filipino	68.7 b	9 150 b
DMS	3.56	3 556
CV	6.5	16.71
Significance	***	**

DMS= minimum significant difference; cv= coefficient of variation; ns= not significant; **= $p\leq$ 0.01; ***= $p\leq$ 0.0001.

Conclusions

The advanced lines of long and thin grain rice presented adaptability to the production area of Michoacán. These materials are superior to the conventional material “Milagro Filipino” in terms of phenological characteristics and their productive components, since they showed consistency in each trial. The treatments FL06747, INIFLAR R and Lombardy presented the highest pellet yields of the evaluations as a whole, even so, the Lombardy treatment due to the agronomic response achieved productive stability, therefore, it provides competitive elements, in addition, its height is similar to the conventional variety, so there is no fall of plants. In general, the materials evaluated are promising for their establishment in Michoacan, replacing the variety “Milagro Filipino”.

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