



Advances in biology through agronomy, aquaculture, coastal and environmental sciences

— Volume II —

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**Advances in biology through
agronomy, aquaculture, coastal and
environmental sciences**
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Advances in Biology through Agronomy, Aquaculture, Coastal and Environmental Sciences, Volume II, is an e-book that continues the work of the first version (<https://editorapantanal.com.br/ebooks/2023/advances-in-biology-through-agronomy-aquaculture-coastal-and-environmental-sciences/ebook.pdf>), published in 2023 by Leandris Argente-Martínez and Ofelda Peñuelas-Rubio.

Our e-book compiles 25 manuscripts that present scientific results and reviews based on biological aspects. All of them contribute to explaining the responses of living organisms to agricultural, aquaculture, and coastal ecosystems, as well as those facing fragility or threat of climate change. This e-book was edited by Leandris Argente-Martínez, Ofelda Peñuelas-Rubio, and Joe Luis Arias-Moscato, members of the Consolidated Academic Group ITVAYA-CA-3.

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Agronomic management for oat seed production in the Bajío region, Mexico

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ABSTRACT

The Bajío agricultural region in Mexico represents a viable option for the production of certified oat seed. During the fall–winter (f–w) growing season, temperature and relative humidity conditions are favorable for the crop, with a low risk of economically significant diseases such as rusts and leaf spot. However, the effects of environmental factors, particularly planting date, on genotype performance—in terms of agronomic variables, yield, and seed physical quality—are unknown. For this reason, experiments were conducted in Celaya, Guanajuato, over three f–w growing seasons, with three planting dates (December 1, 15, and 31) and five genotypes (Chihuahua, Menonita, Karma, Obsidiana, and Turquesa), under irrigated conditions, using a randomized complete block design, where the main plots were the planting dates and the subplots were the varieties, with three replications in each case. The variables evaluated were days to flowering, plant height, panicle length, seed yield, hectoliter weight, and thousand-seed weight. The SREG model was used to analyze yield stability. The model explained 89.26% of the combined effects of genotype, environment, and their interaction. Compared with Menonita, Karma, and Chihuahua, the Obsidiana variety presented the greatest agronomic stability and yield, positioning it as the most desirable; moreover, Chihuahua was classified as unstable, and Obsidiana excelled in yield across the greatest number of evaluated environments.

Keywords: *Avena sativa* L., SREG, environments, genotypes.

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INTRODUCTION

In Mexico, oats are grown primarily for livestock feed. Cultivation is concentrated in the states of Chihuahua, Durango, Mexico, and Zacatecas. In 2024, approximately 562,000 hectares were registered for forage production, with 75% of the area planted during the spring–summer growing season under rain-fed conditions (SIAP, 2026). The nutritional value of grain is high, making it a good option for human consumption because of its contents of amino acids, fiber, β -glucans, protein, and micronutrients (Alemayehu et al., 2023; Li et al., 2024). However, only 45,000 hectares are allocated to grain production under rain-fed conditions (SIAP, 2026); in many cases, farmers set aside part of the commercial crop and use it as a seed, lacking the necessary quality components.

The Mexican Bajío region comprises the states of Querétaro, Jalisco, Michoacán, and Guanajuato. During the fall–winter (f-w) growing season, the region offers favorable temperature and relative humidity conditions for crop development, making it a viable alternative for the production of certified oat seed. The risk of economically significant diseases such as rusts and leaf spots is low (Chávez-Solís et al., 2021; Villaseñor-Mir et al., 2021).

Other factors that influence the production of high-quality seeds include agronomic management. In a study of oat seed germination and seedling development using silicon- and phosphorus-based fertilization, the highest average germination rates and vigor were obtained with the highest K_2SiO_3 fertilization rates of 300 and 450 mg dm⁻³, respectively; in addition, the phosphorus dose influenced seedling development when it was applied at the highest silicon level (Zampar et al., 2011). When organic fertilizer sources were compared with chemical fertilizers, no differences were found in terms of seed yield components, thousand-seed weight, germination percentage, or vigor (Rodríguez-Herrera et al., 2020). The seeding rate also influences yield and quality components. Bobadilla et al. (2013) evaluated the effects of three seeding rates (60, 90, and 120 kg ha⁻¹) and reported positive trends in yield and specific weight as the seed rate increased; in contrast, the thousand-seed weight was affected.

Furthermore, the planting date significantly influences the expression of yield components, phenological development, certain quality attributes, and the incidence of damage caused by biotic and abiotic factors during seed production; therefore, it must be carefully selected to maximize seed production and quality. Furthermore, there is little information on the influence of the environment on the aforementioned variables. Consequently, the objective of this study was to evaluate the performance of five oat genotypes under different environmental conditions (planting dates and growth cycles) in terms of yield components, agronomic characteristics, and seed physical quality.

MATERIALS AND METHODS

Assessment Environments

The experiment was set up on land belonging to the INIFAP Bajío Experimental Farm (CEBAJ), located in Celaya, Guanajuato (20° 35' north latitude and 100° 49' west longitude), at an elevation of 1,756 m. The climate is semiwarm (BS1Hw), with temperatures ranging from 18 to 22°C, an annual average temperature of 21.6°C, and an average annual rainfall of 670.3 mm (García, 1985). Planting was carried out on three dates—December 1, 15, and 31—for three fall–winter growing seasons (2020–2021, 2021–2022, and 2022–2023; hereinafter referred to as cycle 1, cycle 2, and cycle 3, respectively).

Agricultural management

The seeding rate was 90 kg of seed per hectare, and a double-row system with a row spacing of 0.20 m and an interrow spacing of 0.80 m was used. Irrigation was applied at 0, 45, 70, and 90 days after planting, which coincided with the stages of germination, tillering, booting, and grain filling. The fertilizer formula used ranged from 75–40–00; all nitrogen (N₂) and phosphorus (P₂O₅) were applied at planting. For broadleaf weed control, the herbicide 2,4-D Amina was applied at a rate of 1.5 L ha⁻¹. When aphids were identified on the foliage, 50% Oxidemeton-methyl or 1000 Omethoate E was applied at a dosage of 0.25 L ha⁻¹ (García et al., 2016).

Genotypes

The varieties used were Chihuahua (control), Turquesa, Obsidiana, Karma, and Menonita, released by INIFAP's Wheat and Oats Genetic Improvement Program; their agronomic characteristics were evaluated to identify the variety best suited to various environments.

Experimental design

The experiment was set up using a randomized complete block design, where the main factor was the planting date and the secondary factor was the variety, with three replicates for each. Each experimental unit was 16 m² in size, consisting of 4 furrows 5 m long, which were planted in double rows. The variables evaluated were days to flowering, plant height, panicle length, and seed yield at 13% moisture content, which were calculated using the following formula: $P2 = [(100\% - CH1)/87] P1$, where P1 = field weight; P2 = weight adjusted to 13% moisture content; and CH1 = grain moisture content at harvest; for hectoliter weight, the Boerner-type determinator was used as proposed by Moreno (1996), and it was expressed in kg hL⁻¹. The thousand-seed count was performed manually; the seeds were subsequently weighed on an electronic scale (ISTA, 2022).

Statistical analysis

Two groups were formed to analyze the data obtained. Group I included the fall-winter (f-w) cycles of 2021–2022 and 2022–2023 (cycles 2 and 3, respectively) and the varieties Obsidiana, Karma, Chihuahua, and Menonita. Group II included the f-w cycles 2020–2021 and 2022–2023 (cycles 1 and 3), with the varieties Turquesa and Chihuahua. A combined analysis was performed for plots divided by space and time (Steel, Torrie, 1985). The least significant difference (LSD with $p \leq 0.05$) test was used to compare the means. To identify statistically significant differences in the genotype $\times$ environment interaction, the analysis was conducted using the methodology known as SREG (Yan et al., 2000) with GEA-R software (Alvarado et al., 2020); in addition, the yield stability of each variety was determined by assessing how predictable the genotypes' yields are through their evaluation across various environments. The data were analyzed using SAS/STAT® 9.3 software.

RESULTS AND DISCUSSION

Group I

Analysis of Variance

The combined analysis (Table 1) revealed that the growing season was the most significant source of variation for thousand-seed weight, accounting for 85.4% of the total variance in this variable; plant height accounted for 67.7%, and flowering accounted for 62%. Therefore, compared with the variance contributed by the varieties, it can be inferred that the impact of the cycles was 13, 3.2, and 2.1 times greater, respectively, than the variation contributed by the varieties in the expression of the variability of these traits.

Table 1. Mean squares from the randomized complete block design with a split-plot arrangement (divided by time and space) in the combined analysis of four oat varieties over two growing seasons in Celaya, Guanajuato.

Sources of Variation	GL	Yield	Flowering	Plant Height	Panicle Length	Weight of a Thousand Seeds	Hectoliter Weight
Blocks	3	0.82	0.53	0.009	0.002	18.46	1.07
Cycles (C)	1	5.61 **	2480.67 **	1.15 **	0.02 **	576.00 **	39.18
Planting Dates (PD)	2	1.84	110.17 **	0.15 **	0.002	15.32	75.32 **
C*PD	2	20.51 **	157.29 **	0.03 *	0.002	0.39	2.55
Variedades (V)	3	5.21 **	1231.19 **	0.36 **	0.03 **	44.41 **	135.81 **
C*V	3	0.03	1.75	0.009	0.001	8.75	11.78
PD*V	6	0.54	9.71 **	0.004	6×10^{-4}	11.47	2.35
C* PD *V	6	1.92 **	9.71 **	0.006	0.002	18.41	9.22 **
C. V. (C, %)		5.5	1.4	6.7	12.5	8.9	5.8
C. V. (PD, %)		15.8	1.9	6.5	17.2	11.6	2.9
C. V. (V, %)		12.6	1.6	5.6	14.0	7.1	3.4

GL: degrees of freedom; *, ** indicate significance at the 0.05 and 0.01 probability levels, respectively; CV: coefficient of variation

The varieties were the primary determinants of the expression of these traits—hectoliter weight and panicle length—accounting for 49.2% and 46.1% of the total variance in each of these variables, respectively, which was 1.8 and 1.1 times greater than the contribution of the growth stages.

With respect to the importance of interactions, the interaction between growing season and planting date was a key factor in yield expression, accounting for 57.5% of the total variance observed; this effect exceeded that between growing season and variety by 3.7 and 3.9 times, respectively. Therefore, the environmental effect—as mediated by growing season and location—was the most significant source of variation for this variable.

Furthermore, the combined analysis revealed statistically significant differences, with $p \leq 0.01$, among the varieties for all the study variables; among the evaluation cycles or years for all the variables except hectoliter weight; and among the planting dates for flowering, plant height, and hectoliter weight. In terms of the cycles $\times$ planting dates interaction, significant differences were recorded for yield and flowering ($p \leq 0.01$), in addition to differences in plant height at $p \leq 0.05$. In terms of the planting date $\times$ variety interaction, significant differences were detected for the flowering variable ($p \leq 0.01$). For the three-way interaction, statistically significant differences ($p \leq 0.01$) were detected in the yield, flowering, and hectoliter weight variables. With respect to the cycle $\times$ variety interaction, no statistically significant differences were detected in the variables studied. The coefficients of variation for cycles, planting dates, and varieties were acceptable, validating the uniformity in crop management, data collection, and treatment application, as well as the reduced significance that biotic and abiotic stress factors may have had. This allowed for an acceptable experimental error.

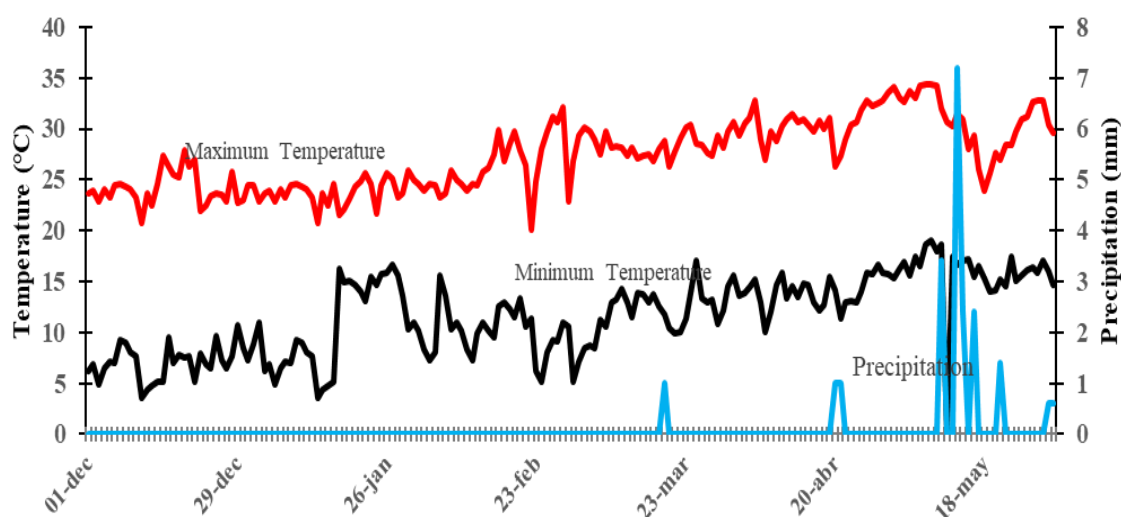


Figure 1. Minimum and maximum temperatures and precipitation in the town of Celaya, Guanajuato, during the second evaluation cycle.

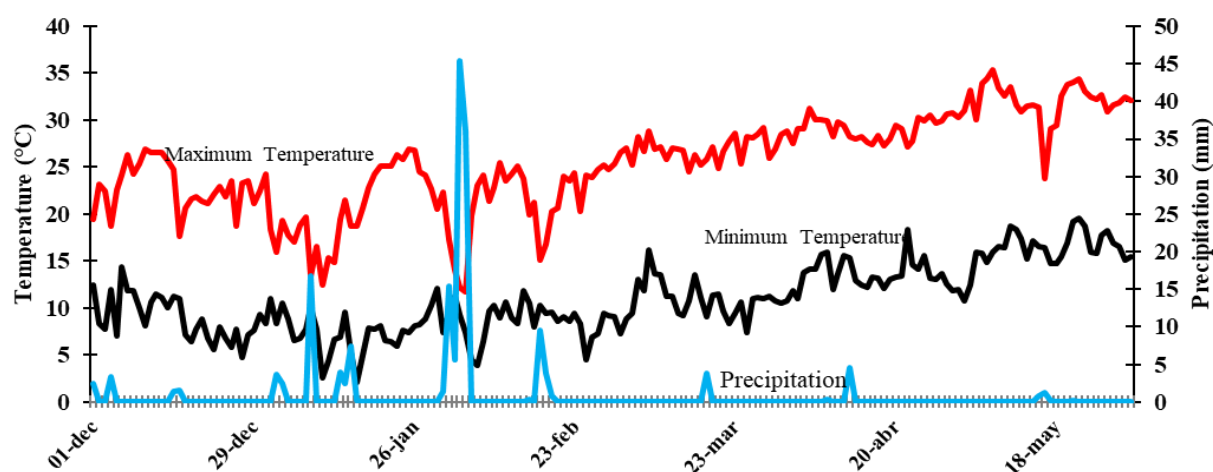


Figure 2. Minimum and maximum temperatures and precipitation in the town of Celaya, Guanajuato, during the third evaluation cycle.

Tests of means

The mean tests for the evaluation cycles (Table 2) revealed that cycle 3 yielded the highest yield, flowering, plant height, panicle length, and thousand-seed weight ($p \leq 0.05$). In other words, environmental conditions were more favorable for the evaluated varieties than for cycle 2, which can be attributed to the fact that only 21 mm of precipitation accumulated in the latter cycle, whereas 175.2 mm accumulated in cycle 3, as shown in Figures 1 and 2, respectively. High temperatures during the anthesis and grain-filling stages in small-grain cereals negatively affect yield by accelerating the rate of senescence (Pinto et al., 2016; Al-Ajlouni et al., 2016; Kim et al., 2024; Lu et al; 2025).

Table 2. Tests of means for fall–winter planting cycles with four oat varieties evaluated in Celaya, Guanajuato.

Cycles	Yield (t ha ⁻¹)	Flowering (days)	Plant Height (cm)	Panicle Length (m)	Weight of a Thousand Seeds (g)	Hectoliter Weight (kg hL ⁻¹)
Cicle 3	4.73 a	92.2 a	1.34 a	0.22 a	36.27 a	42.79 a
Cicle 2	4.25 b	82.0 b	1.13 b	0.19 b	31.37 b	44.07 a
MSD ($p \leq 0.05$)	0.162	0.802	0.054	0.016	1.968	1.644

MSD: Minimally significant difference

Analysis of the planting dates (Table 3) revealed that the highest hectoliter weight was obtained on the first planting date ($p \leq 0.05$), which could be associated with the greater number of days to flowering also observed on this same planting date ($p \leq 0.05$) and the greater plant height ($p \leq 0.05$); that is, to the extent that there was a longer growing season, these variables were most pronounced, regardless of the year or evaluation cycle. This is corroborated by the response of the same variables on December 31, which is when the lowest values were obtained for these variables. This finding is consistent with the

results for beans reported by González et al. (2008), who reported that genotypes with the highest daily yield accumulation or the highest rate of grain weight accumulation achieved the highest yield per unit area. The duration of each phenological stage is associated with absorbed radiation, with a more pronounced effect during flowering through maturity (Royo et al., 2021).

Table 3. Mean planting date test for four oat varieties, evaluated over two fall–winter growing seasons in Celaya, Guanajuato.

Planting dates	Yield (t ha ⁻¹)		Flowering (days)		Plant Height (cm)	Panicle Length (m)		Weight of a Thousand Seeds (g)		Hectoliter Weight (kg hL ⁻¹)
01 December	4.22	a	88.7	a	124	a	0.20	a	34.15	a
15 December	4.64	a	87.6	b	129	a	0.22	a	33.03	a
31 December	4.62	a	85.1	c	116	b	0.20	a	34.28	a
MSD ($p \leq 0.05$)	0.44		1.05		4.9		0.02		2.40	

MSD: Minimally significant difference

Among the varieties evaluated, Obsidiana had the highest seed yield ($p \leq 0.05$) and the highest physical quality ($p \leq 0.05$) and outperformed the other genotypes, followed closely by Karma, which was earlier to flower (days to flowering, $p \leq 0.05$) and had a higher hectoliter weight ($p \leq 0.05$) than did Chihuahua and had the same plant height, panicle length, and stem diameter as Obsidiana were ($p \leq 0.05$). Although Menonita had the lowest seed yield ($p \leq 0.05$), it was the earliest to flower ($p \leq 0.05$) and had the highest seed hectoliter weight ($p \leq 0.05$) and the smallest panicle size ($p \leq 0.05$).

Table 4. Mean values for four oat varieties evaluated over two fall–winter growing seasons in Celaya, Guanajuato.

Varieties	Yield (t ha ⁻¹)	Flowering (days)	Plant Height (cm)	Panicle Length (m)	Weight of a Thousand Seeds (g)	Hectoliter Weight (kg hL ⁻¹)
Obsidiana	5.09a	83.9b	117b	0.21b	35.84a	44.90a
Karma	4.52b	83.9c	115b	0.20b	33.07b	43.38b
Chihuahua	4.40b	97.5a	141a	0.25a	33.40b	40.38c
Menonita	3.96c	81.3d	118b	0.17c	32.97b	45.35a
MSD ($p \leq 0.05$)	0.34	0.86	4.1	0.02	1.43	0.88

MSD: Minimally significant difference

Principal component analysis

In the principal component analysis, as shown in Table 5, the variables that contributed most to the variance in principal component 1 across varieties were days to flowering, panicle length, and hectoliter weight, whereas for principal component 2, they were thousand-seed weight, yield, and plant height. The first two principal components explain 95.2% of the total variance observed across all the

variables in the experiment; therefore, the component model is suitable for explaining the response pattern(s) of the evaluated oat varieties and their variables.

Table 5. Eigenvectors and proportion of variance explained by the two principal components (PC) in the oat study across two fall-winter growing seasons and three planting dates.

Variables	Characteristic vectors	
	PC1	PC2
Yield	0.070	0.661
Flowering	-0.423	-0.034
Plant height	0.406	-0.131
Panicle length	0.408	0.113
Thousand-seed weight	0.028	0.683
Hectoliter weight	-0.386	0.207
Characteristic value	5.568	2.050
Percentage of variance explained	69.6	25.6

The distribution of the four varieties is shown in Figure 3, with the Obsidiana variety characterized by the highest yields and thousand-seed weights, but it also exhibited a short plant height and intermediate maturity (Espitia et al., 2007). Karma had a lower yield but outperforms Chihuahua and Menonita, with intermediate maturity, similar to that of Obsidiana, but earlier than Chihuahua and lower hectoliter weight than Obsidiana. Compared with the other evaluated genotypes, Menonita had the earliest flowering and the highest hectoliter weight, but its yield was low, similar to that of Chihuahua. Chihuahua was the latest to flower and had the lowest hectoliter weight, which puts it at a disadvantage compared with the other varieties since Obsidiana and Karma outperform it in yield and have fewer days to flowering; Menonita is the best option for environments (cycles and planting dates) where the production cycle is short because of its earlier maturity. In this context, Zamudio-Colunga et al. (2023) reported that the Chihuahua variety is susceptible to leaf and stem rust and is largely surpassed by newly released varieties.

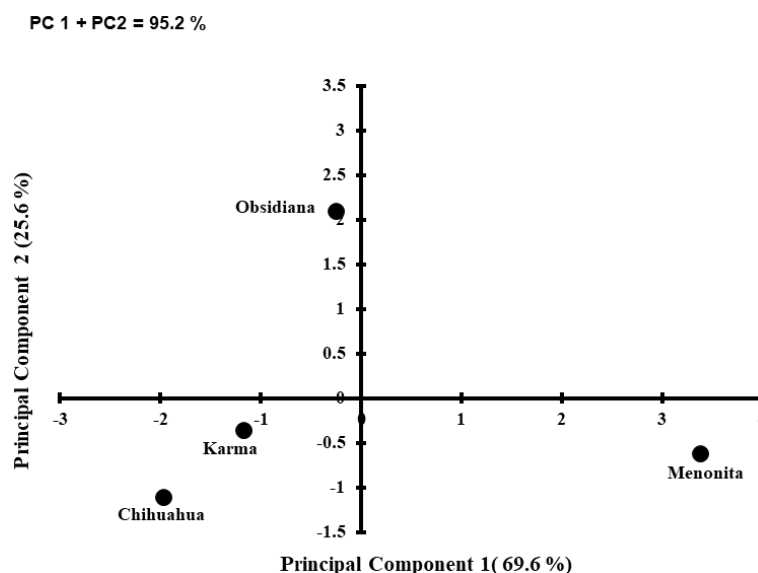


Figure 3. Variability of four oat varieties based on principal component analysis, evaluated over two fall–winter growing seasons and three planting dates under irrigated conditions, Celaya, Guanajuato.

Group II

Analysis of variance

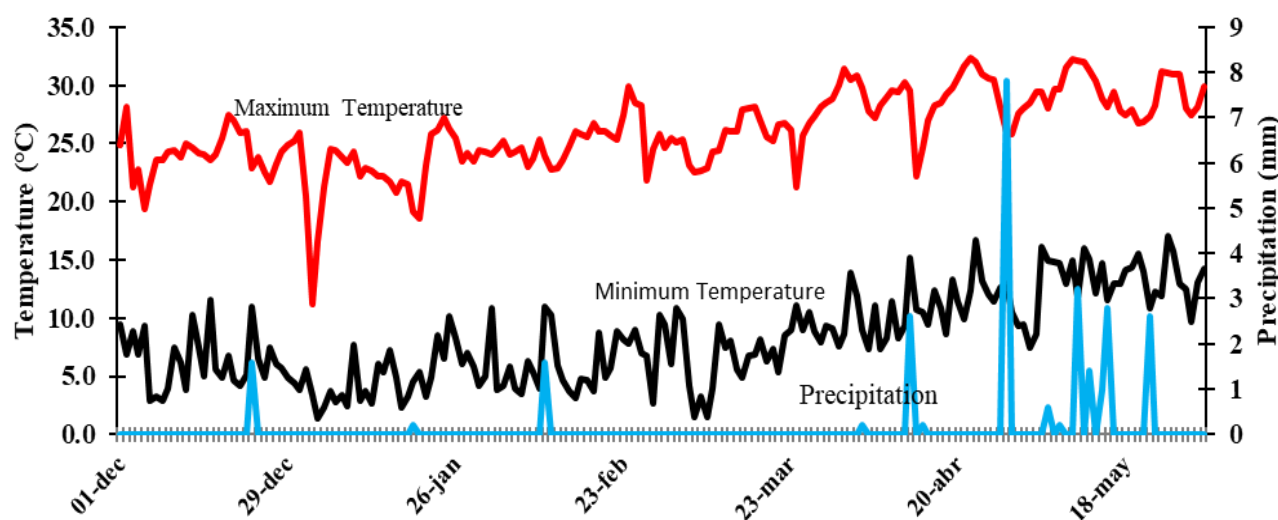
The combined analysis (Table 6) revealed that the varieties accounted for the greatest proportion of variance in the expression of the variable's hectoliter weight, plant height, thousand-seed weight, days to flowering, and panicle length: 81.4%, 69.1%, 66.7%, 64.8%, and 45% of the total, respectively. Only in terms of yield was the contribution of variance due to cycles greater (71.2% of the total), and for days to flowering, it contributed 26.7% of the variance. The planting date was the second-largest source of variation, contributing 39.1% of the total variance in panicle length and, similarly, 17.3% of the total variance in plant height; these variables were surpassed in importance only by the varieties for the latter variable.

With respect to the interactions, the one with the greatest impact was cycles by variety on the yield variable, accounting for 13.4% of the total variance and 5.9% of the variance in panicle length, followed by cycles by planting date on thousand-seed weight, accounting for 10.3% of the total variance recorded and 5.3% of the total variance in plant height. Once again, the coefficients of variation confirm that the experimental error due to factors outside the statistical model used was low, which ensures the reliability of data collection and the uniform application of the evaluated treatments: cycles, planting dates, and varieties.

Table 6. Mean squares from the randomized complete block design with a split-plot arrangement (divided by time and space) in the combined analysis of two oat varieties over two fall-winter growing seasons in Celaya, Guanajuato

Sources of Variation	GL	Yield	Flowering	Plant Height	Panicle Length	Weight of a Thousand Seeds	Hectoliter Weight
Cycles (C)	1	33.33 *	693.44 **	5.44	0.0008	6.17	16.851
Blocks	2	1.84	0.33	180.19	0.0002	0.60	74.42
Planting Dates (PD)	2	2.27 *	110.58 **	529.19	0.0053	18.78	74.42 **
C* PD	2	1.26	64.36 **	162.03	0.0002	23.86	9.67 **
Varieties (V)	1	2.91 *	1681.0 **	2116.0 **	0.0061 *	155.0 **	460.89 **
C*V	1	6.28 **	1.78	128.44	0.0008	11.00	0.07
PD *V	2	0.38	18.58 *	78.08	0.0003	13.35	2.85
C* PD *V	2	0.37	24.36 **	41.03	0.00005	4.24	1.63
C. V. (C, %)		23.4	1.8	10.4	20.2	9.6	6.2
C. V. (PD, %)		12.4	1.9	8.6	14.1	9.8	3.2
C. V. (V, %)		12.4	1.6	10.7	10.2	8.9	3.3

GL: degrees of freedom; *, ** indicate significance at the 0.05 and 0.01 probability levels, respectively; CV: coefficient of variation

**Figure 4.** Minimum and maximum temperatures and precipitation in the town of Celaya, Guanajuato, during the first evaluation cycle.

Mean test

With respect to the varieties evaluated, the data in Table 7 show that, as in Group I, Variety 3 outperforms Variety 1, surpassing it statistically ($p \leq 0.05$), with 1.9 t ha^{-1} of seed and 8.8 more days of flowering; although no significant differences were detected, a trend toward higher seed hectoliter weight was observed in cycle 3. The environmental differences are likely associated with higher precipitation during the vegetative phase of the third evaluation cycle and the presence of rain during the harvest stage in cycle 1 (Figures 2 and 4, respectively); this pattern is consistent with that reported by Rodríguez-Herrera et al. (2020).

Table 7. Mean test for two fall-winter planting cycles, using two oat varieties, evaluated in Celaya, Guanajuato.

Cycles	Yield (t ha ⁻¹)	Flowering (days)	Plant Height (cm)	Panicle Length (m)	Weight of a Thousand Seeds (g)	Hectoliter Weight (kg hL ⁻¹)
Cycle 3	5.256 a	96.0 a	114.8a	0.245a	31.400a	42.312a
Cycle 1	3.332 b	87.2 b	115.6a	0.254a	32.228a	40.944a
MSD (p ≤ 0.05)	1.442	2.390	17.192	0.072	4.407	3.712

MSD: Minimally significant difference

Among the planting dates (Table 8), and similar to the response of the first group (Table 3), the early dates (December 1 and 15) presented better environmental conditions ($p \leq 0.05$) for obtaining higher yields, outperforming the third planting date (December 31), with a similar response in plant height and days to flowering between the first two dates. Among the evaluated varieties, December 1 offered the best environmental conditions ($p \leq 0.05$) for achieving the highest hectoliter weight. In other words, as the growing cycle lengthened, yield, days to flowering, plant height, and hectoliter weight increased; this was true regardless of the cycles and varieties evaluated.

Table 8. Test of means for planting dates for two oat varieties evaluated over two fall–winter growing seasons in Celaya, Guanajuato.

Planting dates	Yield (t ha ⁻¹)	Flowering (days)	Plant Height (cm)	Panicle Length (m)	Weight of a Thousand Seeds (g)	Hectoliter Weight (kg hL ⁻¹)
December 01	4.546 a	93.2 a	114.7 ab	0.236 a	33.033 a	44.446 a
December 15	4.541 a	93.5 a	122.1 a	0.274 a	30.533 a	40.715 b
December 31	3.792 b	88.1 b	108.9 b	0.238 a	31.875 a	39.723 b
MSD (p ≤ 0.05)	0.607	2.017	11.284	0.039	3.568	1.510

MSD: Minimally significant difference

Among the varieties evaluated in this group (Table 9), Turquesa statistically outperformed ($p \leq 0.05$) Chihuahua in terms of yield, with 569 kg ha⁻¹; this was likely due to a higher thousand-seed weight (4.15 g) and a higher hectoliter weight (7.156 kg hL⁻¹) than Chihuahua. The latter, however, has a longer growing season (days to flowering), greater plant height, and longer panicle length; it did not exhibit sufficient physiological efficiency to outperform Turquesa in yield.

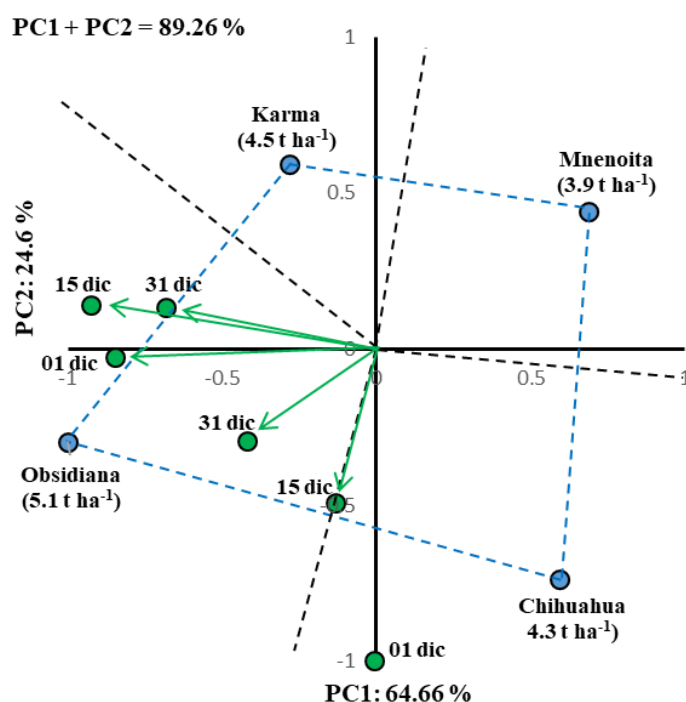
Table 9. Analysis of means for two oat varieties based on agronomic variables and seed quality, evaluated over two fall-winter growing seasons in Celaya, Guanajuato.

Varieties	Yield (tha ⁻¹)	Flowering (days)	Plant Height (cm)	Panicle Length (m)	Weight of a Thousand Seeds (g)	Hectoliter Weight (kg hL ⁻¹)
Turquesa	4.579 a	84.3 b	107.6 b	0.236 b	33.888 a	45.206 a
Chihuahua	4.010 b	98.5 a	122.9 a	0.262 a	29.738 b	38.050 b
MSD ($p \leq 0.05$)	0.435	1.206	10.099	0.020	2.330	1.145

MSD: Minimally significant difference

Genotype–Environment Interaction Analysis (SREG biplot) Group I

On the basis of the results of the genotype analysis and the genotype–environment interaction (Figure 5), it can be concluded that compared with those in cycle 2, the response in cycle 3 was very different. The planting dates of December 15 and 31 in cycle 3 were similar in terms of yield expression among the oat varieties, with the former yielding the highest average. In the cycle 2 trials, the highest yield was obtained on December 1, and the date with the greatest environmental stress for the expression of this trait was December 31.

**Figure 5.** Genotype–environment interactions of four oat varieties across three planting dates and two fall-winter growing seasons, using the SREG model and the “which variety performed best where” framework; Celaya, Guanajuato.

Among the varieties, Obsidiana had the highest yield on the basis of the projection of the vector from the origin to the point representing each variety, followed by Karma, Chihuahua, and Menonita. Notably, Obsidiana achieved the highest yields on all the planting dates, except for December 1 of cycle 2, which is why it was located at the vertex of the “which-won-where” polygon among the genotypes

with respect to the environments, followed by Karma; at the bottom, without having stood out in yield on any of the planting dates, Chihuahua and Menonita were. On the basis of the above, it can be concluded that the highest yields were achieved during early planting dates (December 1 and 15), regardless of whether the growing seasons were favorable, such as in cycle 3, or stressful, such as in cycle 2. On the basis of the experimental data, among the early planting dates, there is a tendency to obtain higher yields in favorable environments (cycles or years) on December 15 and in less favorable environments on December 1.

Performance Stability Analysis

On the basis of the rotation of the x-axis, the definition of the average environment, and the drawing of a line perpendicular to the x-axis, the stability of the genotypes was determined (Figure 6). On the basis of the deviations from the x-axis of the average environment, compared with Menonita, Karma, and Chihuahua, the Obsidiana variety presented the highest agronomic stability (Becker, 1981) and yield; this makes it the most promising variety according to Yan and Kang (2003); the stability of Menonita and Karma was lower, with Chihuahua being the least stable. In other words, the yield of Chihuahua was difficult to predict on the basis of the evaluation cycles. The same figure shows that the y-axis allows the varieties' yields to be classified into two major groups: First, Chihuahua and Menonita had seed yields below the overall average, and in the second group, Obsidiana and Karma exceeded that average yield. The model's coefficient of determination is considered acceptable (89.26%), according to Yan and Rajcan (2002); thus, the interpretation of the figure is reliable.

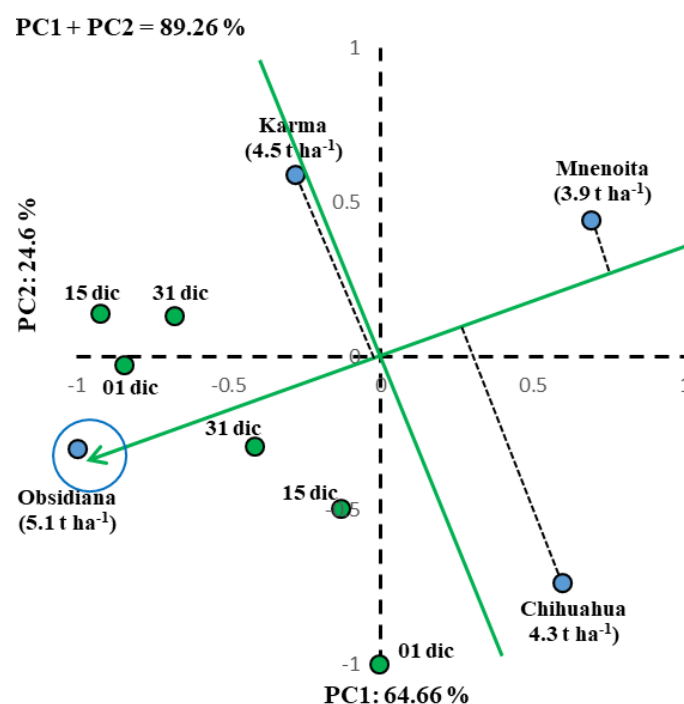


Figure 6. Yield stability of four oat varieties across six environments (with three planting dates and two growing seasons): Celaya and Guanajuato.

CONCLUSIONS

Growing conditions (cycles) and varieties are the most important factors for determining seed yield and physical quality and are closely related to a crop's phenological stage, as well as whether the variety is early-maturing or late-maturing. Among the six varieties evaluated, Obsidiana had the highest yield, and Menonita had the lowest yield because it is an early-maturing variety. Chihuahua was used as a control and had lower yields than Obsidiana did. The greatest difference among the environments was the total accumulated precipitation and its distribution during the crop development phase. Obsidiana is considered the most desirable variety because of its high and stable seed yield; it was the best variety in five of the nine evaluation environments, which was justified by its higher hectoliter weight and thousand-seed weight, as well as its smaller plant size.

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