Revista Mexicana de Ciencias Agrícolas

DOI: https://doi.org/10.29312/remexca.v16i8.3940

Articule

Grain yield stability of rainfed oat varieties in the High Valleys of Mexico

René Hortelano Santa-Rosa[1]
Héctor Eduardo Villaseñor-Mir[1]
Salvador Carranza-González[2,§]
Eliel Martínez-Cruz[1]
Yerica Renata Valdez-Rodríguez[2]
Julio Huerta-Espino[1]

1 Campo Experimental Valle de México-INIFAP. Carretera Los Reyes-Texcoco km 13.5, Coatlinchán, Texcoco, Estado de México. CP. 56250.

2 Colegio de Postgraduados- Campus Montecillo-Posgrado en Recursos Genéticos y Productividad. Carretera México-Texcoco km 36.5, Montecillo, Texcoco, Estado de México. CP. 56230.

Autor para correspondencia: ŎŀЖŀ·ƴÎŀ·ǉăŀ·fØŀ·ŘƧЖƳŎƧſŁJƧăǉYÈǉ

Abstract

The grain yield stability of 12 oat varieties was evaluated in 23 localities situated in rainfed environments of the High Valleys of Mexico. Two methodologies were used to assess grain yield stability: Eberhart and Russell parameters and AMMI analysis. The stability parameters allowed us to better discriminate the varieties through the interaction they had in the environments; these parameters showed similar results to each other, in which the Ágata variety stood out for its high yield, stability, and consistency; in second place were Turquesa and Menonita, while the Cuauhtémoc, Papigochi, and Avemex varieties were the least suitable genotypes. The results showed classifying the varieties with the highest qualities for recommendation and those that no longer have potential for commercial use.

Palabras clave:

Avena sativa L., genotype × environment interaction, rainfed environments, yield stability.

DOI: https://doi.org/10.29312/remexca.v16i8.3940

Introduction

Oats (*Avena sativa* L.) are the seventh most important cereal worldwide, with an annual production of 18.7 million tons of grain. The importance of this crop lies in its hardiness and adaptability to diverse environments, its versatility for forage uses, and its use of grain for human consumption (FAO, 2024). Since the beginning of crop breeding, there has been an effort to privilege the development of varieties with genetic combinations that combine high yield, higher quality, and adaptability to various production environments (Liu *et al*., 2016; Mehraj *et al*., 2017). Plant breeders have worked to develop good-quality, consistent, and high-yielding cultivars; such cultivars are highly desired to adapt to a wide range of environments (Mut *et al*., 2018). It is a crop that stands out for being more suitable than others in marginal lands, such as high and cold areas, as well as in infertile and arid areas (Buerstmayr *et al*., 2007).

In Mexico, in 2023, about 352 000 ha of forage oats were planted, with a production of 2.9 million tons with an average yield of 8.23 t ha^{-1}; in contrast, in the High Valleys of Mexico, that year, about 104 000 ha were planted for forage, obtaining an average yield of 16.6 t ha^{-1} and about 37 000 ha for grain, with an average yield of 2.4 t ha^{-1} (SIAP, 2024); at the national level, this crop is highly adaptable to high, cold and rainy areas, as well as to semi-arid environments and is an alternative when crops such as corn, beans, wheat, or barley are damaged by drought or early frosts (Villaseñor *et al*., 2021).

Yield stability cannot be directly measured in a field experiment in one year, it must be evaluated in various locations or environments for several years (Reckling *et al*., 2021); this concept is useful for plant breeders who develop genotypes adapted to a wide range of environmental conditions (Mühleisen *et al*., 2014); in addition, in recent years, there has been a greater variability in climatic conditions, which is associated with lower stability of crop yields (Müller *et al*., 2018; Tigchelaar *et al*., 2018).

For the study of genotype × environment interaction (GEI), among all the statistical analyses developed, the most used are the GGE biplot and the Additive Main Effects and Multiplicative Interaction (AMMI) models (Dyulgerova *et al*., 2020). The AMMI model is efficient because it captures much of the sum of squares of the GEI, accurately separates the main effects, and provides a meaningful interpretation of the data (Ebdon and Gauch, 2002); it also allowed us to understand the interactions of the GEI of genotypes in multiple environments (Luo *et al*., 2015).

Given this scenario, studies are needed to develop oat materials that meet the aforementioned requirements. This work is conceptualized as a tool for the selection of materials to be planted and thus achieve a positive impact on production; therefore, the objectives were to determine the stability of grain yield of oat varieties across rainfed environments in the High Valleys of Central Mexico and to identify high-yielding, stable and consistent varieties.

Materials and methods

The study utilized information from 12 oat varieties released by INIFAP's Oat Genetic Improvement Program, which were evaluated under rainfed conditions using an experimental design in complete blocks with randomized treatments (DCBRT) with two replications. The size of the experimental plot was four rows, each measuring three meters in length and spaced 30 cm apart, with the useful plot being the total of the experimental plot (4.5 m^2). The agronomic variables evaluated were days to flowering (DF), days to physiological maturity (DM), plant height (PH), and grain yield (YIE); however, for the present study, the variable of interest is YIE.

The agronomic management of the crop followed guidelines recommended by INIFAP according to each region. Each variety was established in 23 environments, which have been cataloged depending on the conditions they present; the classification proposed by Villaseñor and Espitia (2000) considers the following: favorable environments, those with rainfall greater than 600 mm during the growing season and well distributed, soils with good moisture retention, low temperatures at the end of the cycle and high relative humidity; intermediate environments, with precipitation

Revista Mexicana de Ciencias Agrícolas

DOI: https://doi.org/10.29312/remexca.v16i8.3940

ranging from 400 to 600 mm during the growing season and regularly distributed, soils with regular moisture retention and low temperatures at the end of the cycle. Critical environments, with rainfall of less than 400 mm during the growing season and poorly distributed, thin soils with low moisture retention, and low temperatures at the end of the cycle. Table 1 groups the evaluated localities by the type of environment to which they belong, as well as the average of the variables evaluated for the 12 varieties.

Table 1. Means of variables evaluated of 12 oat varieties, in 23 environments, and by type of environment in the High Valleys.

TE	NLoc	Locality	YIE	DF	DM	PH
Favorable	20	Tlalmanalco, Mexico	2 946	61	-	115
	9	Juchitepec, Mexico	2 749	65	125	104
	23	Santa Lucía, Mexico	2 337	60	-	98
	11	Nanacamilpa, Tlaxcala	2 169	-	-	99
	19	Miraflores, Mexico	2 125	60	100	99
	2	Nanacamilpa, Tlaxcala	2 081	68	-	125
	16	Chapingo 1F, Mexico	2 080	65	99	105
	18	Nanacamilpa, Tlaxcala	2 079	63	-	116
	Means for favorable		2 320.7	63.1	108	107.6
Intermediate	17	Chapingo 2F, Mexico	1 941	56	98	100
	15	Tlalmanalco, Mexico	1 774	-	117	99
	7	Tlalmanalco, Mexico	1 727	61	100	111
	8	Coatepec, Mexico	1 726	65	100	108
	22	Terrenate, Tlaxcala	1 534	62	110	94
	12	Fco. I. Madero, Tlaxcala	1 527	61	104	104
	14	Coatepec, Mexico	1 520	59	-	100
	Means for intermediate		1 603.8	60.6	104.8	102.2
Critical	5	Chapingo, Mexico	1 419	58	95	117
	6	Santa Lucia, Mexico	1 415	59	116	122
	21	Chapingo, Mexico	1 207	54	-	108
	4	Velasco, Tlaxcala	1 099	63	113	95
	10	Santa Lucía, Mexico	977	57	111	94
	3	Terrenate, Tlaxcala	965	61	113	93
	1	Soltepec, Tlaxcala	947	65	115	114
	13	Soltepec, Tlaxcala	916	60	108	93
	Means for critical		1 147	59.5	110.5	106.1
	Tukey (α= 0.05)		481.2	2.7	2.3	7.6

TE= type of environment; NLoc= number of localities; DF= days to flowering; DM= days to maturity; PH= plant height in cm; YIE= grain yield; - = no data.

DOI: https://doi.org/10.29312/remexca.v16i8.3940

Biological material

The varieties used were Ágata, Jade, Turquesa, Obsidiana, Avemex, Karma, Teporaca, Menonita, Papigochi, Diamante R31, Cuauhtémoc, and Chihuahua, which INIFAP released at different times.

Statistical analysis

The statistical analysis and generation of stability parameters were performed using the program Genotype × Environment Analysis with R for Windows (GEA-R) version 1.2, developed by the International Maize and Wheat Improvement Center (CIMMYT, by its Spanish acronym). The evaluation of the genotype × environment interaction (GEI) was performed using the AMMI analysis, which is a model of additive main effects and multiplicative interaction proposed by Gauch and Zobel (1988).

Results and discussion

Table 2 presents the values obtained for each methodology, where it is possible to observe that for Eberhart and Russell (1966), the regression coefficients and the deviation of the regression are used. Likewise, the possible situations of the values of the stability parameters were considered.

Table 2

Stability parameters evaluated for the 12 oat varieties according to Eberhart and Russell (1966) and classification by Carballo and Márquez (1970), in 23 environments.

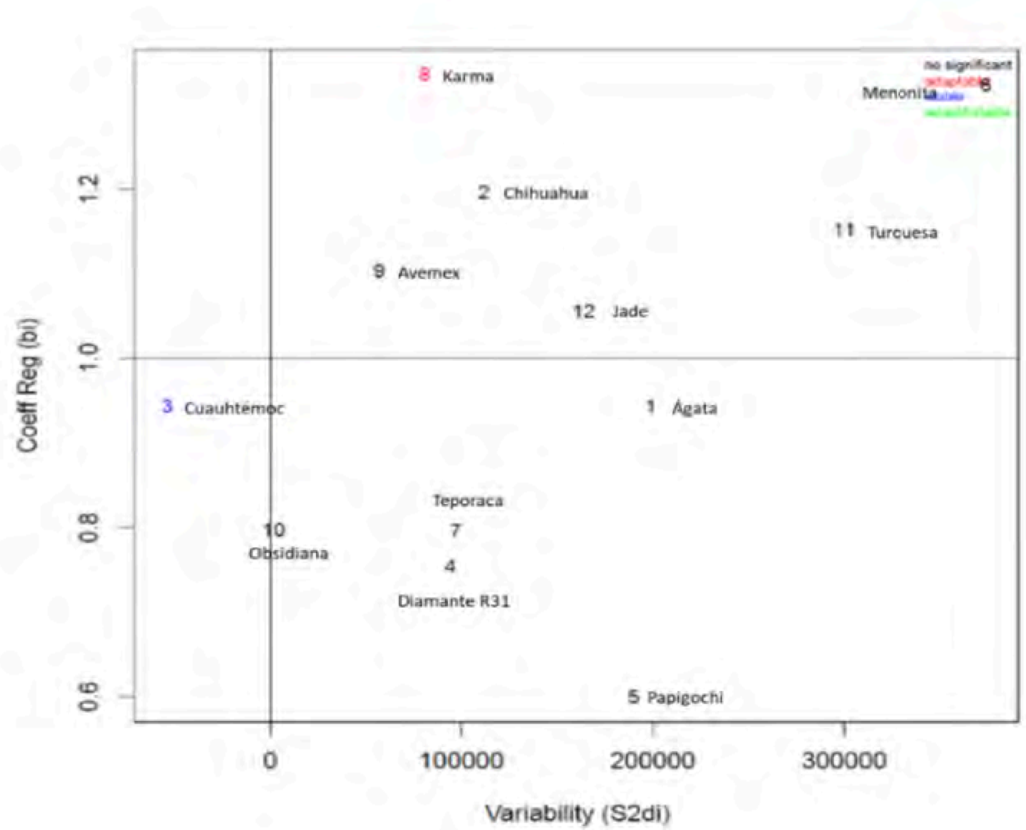
Genotype	Mean	Eberhart and Russell		Classification
		bi	S^2di	
Ágata	2 488.3	0.944	198749.04	S
Turquesa	2 177.5	1.153	300013.31	S
Menonita	2 064.8	1.323	374888.09	TI
Teporaca	1 814.5	0.795	97099.58	DI
Diamante R31	1 807.8	0.754	94304.54	DI
Jade	1 652.3	1.056	163836.25	S
Karma	1 638.3	1.336	80806.1	TI
Chihuahua	1 622.7	1.196	111782.33	S
Obsidiana	1 593	0.797	1850.8	DI
Cuauhtémoc	1 243.3	0.944	-53690.23	S
Avemex	1 178.8	1.104	57027.51	S
Papigochi	1 168.5	0.6	190106.34	DI

Mean= mean grain yield in general; bi= coefficient of regression; S^2di= deviation of the regression, classification given by Carballo and Márquez (1970); S= stable variety; DI= good response in unfavorable and inconsistent environments; TI= it responds well in all environments, but inconsistent.

Figure 1 shows the results plotted and obtained through the stability parameters of Eberhart and Russell, where the behavior of the 12 varieties is observed by means of the regression coefficients and the deviation of the regression; if the regression coefficient (bi) is close to 1, they are considered to be adaptive genotypes; if the deviation of the regression (S^2di) is close to zero, they are stable genotypes.

DOI: https://doi.org/10.29312/remexca.v16i8.3940

Figure 1. Yield stability parameters (regression coefficient, bi and variability or deviation of the regression, S^2di) obtained through the analysis of Eberhart and Russell (1966).



Eberhart and Russell emphasized considering the linear (bi) and nonlinear (S^2di) components of GxE interactions when judging the stability of a genotype (Akcura *et al*., 2005). According to what was obtained, it is highlighted that variety 3 (Cuauhtémoc) is considered stable, but with low yield, whereas variety 8 (Karma), considering the classification of Carballo and Márquez (1970), responds well in all environments, but is inconsistent; the rest of the varieties do not show significant behavior. Similarly, the regression deviations are non-zero, which aligns with Rodríguez *et al*. (2002), who determined that the linear model is not appropriate for describing the response of genotypes as a function of environmental effect; according to this criterion, the genotypes mentioned would not be stable.

Rodríguez *et al*. (2002) stated that lower regression coefficients, bi< 1, indicate genotypes with relative adaptation to unfavorable environments, while genotypes with values of bi> 1 indicate that they respond adequately to environmental improvements. In the present study, the Obsidiana, Teporaca, Diamante R31 and Papigochi varieties have regression coefficients lower than 1, which makes them varieties that respond better in unfavorable environments; for their part, Avemex, Chihuahua, Karma, Turquesa and Menonita, with regression coefficients equal to or greater than 1, are considered genotypes that respond adequately to better environments.

Table 3 presents the results obtained from the AMMI analysis, in which, according to the Gollob test (Vargas and Crossa, 2000), five principal components represent important variability; the first only considers 34.57% of the variability of the GEI or of the sum of squares of this source of variation, so the discrimination of genotypes using this study technique may be somewhat limited, coinciding with the results reported by Dyulgerova *et al*. (2020), which demonstrates the need to perform

Revista Mexicana de Ciencias Agrícolas

DOI: https://doi.org/10.29312/remexca.v16i8.3940

tests in various environments to identify stable and high-yielding lines; likewise, García *et al*. (2021) mention that the advantage of the AMMI model can be seen in identifying genotypes with superior yields and high stability from those with medium yields, but with specific adaptation.

Table 3. AMMI analysis for grain yield of 12 oat varieties evaluated in 23 rainfed environments of the High Valleys.

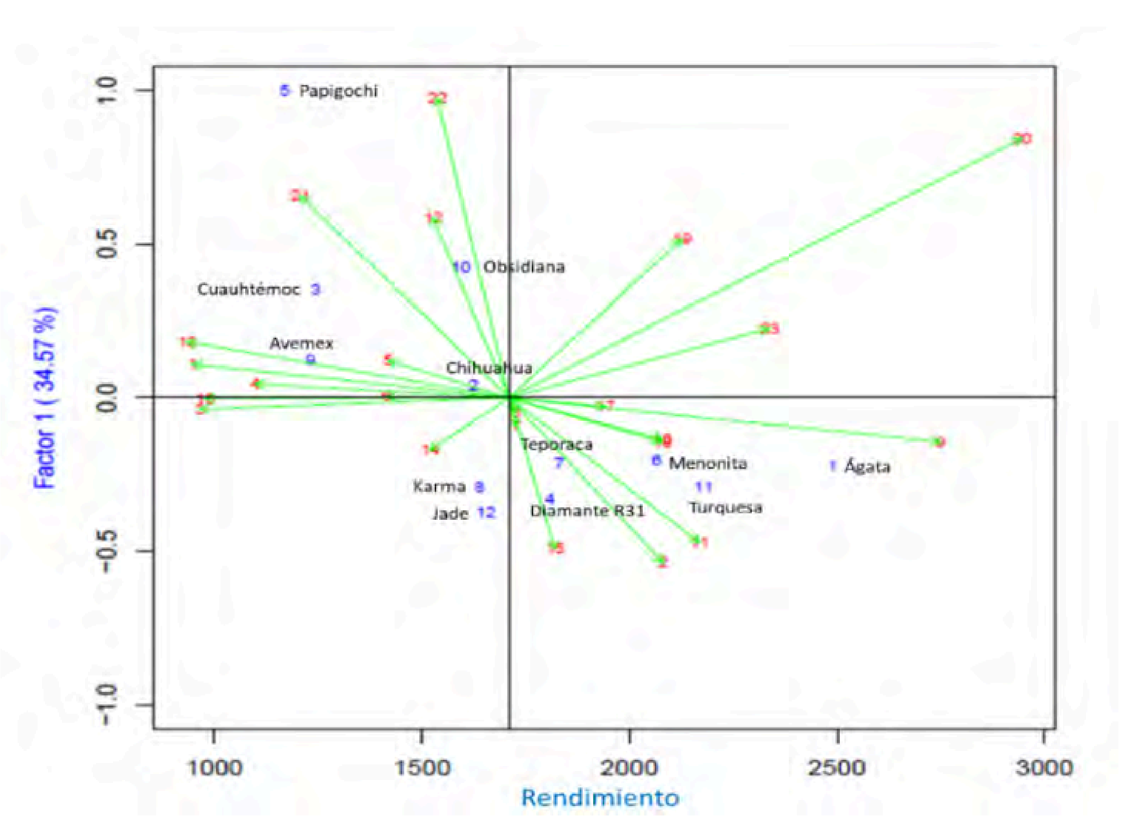
	df	SS	MS	Percent 1 (%)	Percent 2 (%)
Environments	22	168683184.5	7667417.48**	45.37	45.37
Genotypes	11	81600679.03	7418243.55**	21.95	67.31
Environments*Genotypes	242	121542828.22	502243.09**	32.69	100
PC1	32	36747195.51	1148349.86**	34.57	34.57
PC2	30	18998510.23	633283.67**	17.87	52.44
PC3	28	14258880.65	509245.74**	13.41	65.85
PC4	26	11104541.8	427097.76*	10.45	76.3
PC5	24	9147989.78	381166.24*	8.61	84.9
PC6	22	4921587.26	223708.51ns	4.63	89.53
PC7	20	3803492.72	190174.64ns	3.58	93.11
PC8	18	3238951.84	179941.77ns	3.05	96.16
PC9	16	1892125.45	118257.84ns	1.78	97.94
PC10	14	1216636.44	86902.6ns	1.14	99.08
PC11	12	976319.58	81359.97ns	0.92	100
PC12	10	0	0	0	100
Residual	273	56332109	206344.72	0	0

df= degrees of freedom; SS= sum of squares; MS= mean square; Percent 1 (%)= percentage of the sum of squares of each term with respect to the total genotype × environment interaction of each AMMI term; Percent 2 (%)= percentage of the total sum of squares of the genotype × environment interaction of each AMMI term, but accumulated up to the respective term.

Figure 2 shows the results of the AMMI analysis for the 12 varieties evaluated in the 23 environments, which were obtained from Table 2. The results are easier to interpret when genotypes and environments are presented graphically (GGE Biplot). The grain yield of the genotypes and environments is read on the x-axis.

Revista Mexicana de Ciencias Agrícolas
REMEXCA
DOI: https://doi.org/10.29312/remexca.v16i8.3940

Figure 2. GGE biplot of the AMMI analysis for grain yield of 12 oat varieties evaluated in 23 rainfed environments of the High Valleys.



The line perpendicular to this axis indicates the average yield, so the inputs with the lowest yield are plotted to the left of this axis, and the varieties and environments with the highest yield are located to the right. On the other hand, the y-axis measures the stability of genotypes and environments: those with values close to zero are stable, while those with high values of the first principal component are unstable. Generally, the recommendations of the best are based on the average performance of the genotypes across environments (Adnan *et al*., 2020); likewise, the biplot allows the selection of stable and superior genotypes in multiple environments, as stated by Khan *et al*. (2021).

According to the information generated, the Chihuahua and Avemex varieties were the most stable, but they registered low yields; in contrast, the Ágata, Menonita and Turquesa varieties were the most stable and those that registered the highest yields, although the higher productivity of Ágata is evident. On the other hand, the Cuauhtémoc, Diamante R31, Papigochi, Karma, Obsidiana and Jade were the most unstable varieties as they were far from the zero value of the y-axis (2) and some of them registered the lowest yields.

Environment 20 (Tlalmanalco, Mexico) had the highest yield, and since it has the longest vector, it is inferred that it discriminated the genotypes better compared to environment 13 (Soltepec, Tlaxcala), which registered the lowest yield. Environments 5, 6, 7, 8 and 14 had the shortest vectors, indicating that they did not discriminate genotypes; that is, most of them showed a similar response.

Through the AMMI analysis, the varieties that were the most stable and yielding were Ágata, Turquesa, and Menonita, as their values in the yield component fell within the parameters established by this model, which in turn allows us to indicate that the test is adequate for the present research.

DOI: https://doi.org/10.29312/remexca.v16i8.3940

One of the most common tests to determine stability in genotypes across environments is that of Eberhart and Russell (1966), through which, for the present study, it was determined that the varieties that showed stability were Ágata, Jade and Cuauhtémoc, whereas the least stable varieties, but with adaptation to unfavorable environments, were Obsidiana, Teporaca, Diamante R31 and Papigochi; for their part, the Chihuahua, Karma, Turquesa, Menonita and Avemex varieties improved their performance in response to improved environmental conditions, combination of precipitation, soil moisture, as reported by Villaseñor and Espitia (2000), since in the latter, their *bi* was greater than one.

Ágata was the most outstanding variety with conventional analyses of variance, expressing itself as a high-yielding variety, as pointed out by Villaseñor *et al*. (2018), who described it as a variety with the best response in all environments, but inconsistent, which is not adequate, since consistency across environments is important in the High Valleys of Mexico.

Conclusions

The evaluation of the varieties in various contrasting environments enabled us to discriminate among them in the best way, as they all presented significance in the GEI. The results of the methods to determine stability were not consistent; nevertheless, they agree in pointing to the Ágata variety as the most stable and high-yielding, and the Papigochi, Jade and Karma varieties were the most unstable. With the implementation of these methodologies, it is proposed to continue recommending stable and high-yielding varieties, such as Ágata and to stop using Papigochi, Cuauhtémoc, and Avemex because they are unstable, inconsistent, and low-yielding.

Acknowledgements

We thank INIFAP for financing the research through the fiscal project: ‘generation of oat varieties to increase productivity in Mexico’ with SIGI number 9165636496.

Acknowledgements

We thank INIFAP for financing the research through the fiscal project: ‘generation of oat varieties to increase productivity in Mexico’ with SIGI number 9165636496.

Bibliography

1 Adnan, A. A.; Diels, J.; Jibrin, J. M.; Kamara, A. Y.; Shaibu, A. S.; Craufurd, P. and Menkir, A. 2020. CERES-maize model simulating genotype-by-environment interaction of maize and its stability in the dry and wet savannas of Nigeria. Field Crops Research. 253:107826. https://doi.org/10.1016/j.fcr.2020.107826.

2 Akcura, M.; Ceri, S.; Taner, S.; Kaya, Y. Ozer, E. and Ayranci, R. 2005. Grain yield stability of winter oat (*Avena sativa* L.) cultivars in the central Anatolian region of Turkey. Journal of Central European Agriculture. 6(3):203-210.

3 Buerstmayr, H.; Krenn, N.; Stephan, U. Grausgruber, H. and Zechner, E. 2007. Agronomic performance and quality of oat (*Avena sativa* L.) genotypes of worldwide origin produced under Central European growing conditions. Field Crops Research. 101(3):343-351. https://doi.org/10.1016/j.fcr.2006.12.011.

4 Carballo, C. A.; Márquez, S. F. y Molina, G. J. 1970. Comparación de variedades de maíz del Bajío y de la Mesa Central por su rendimiento y estabilidad. Agrociencia. 5(1):129-146.

5 Dyulgerova, B. and Savova, T. 2020. Genotype by environment interaction for grain yield in winter oat. Bulgarian Journal of Agricultural Science. 26(5):992-997.

DOI: https://doi.org/10.29312/remexca.v16i8.3940

6 Ebdon, J. S. and Gauch, H. G. 2002. Additive mean effect and multiplicative interaction analysis of national turfgrass performance trials: 1. Interpretation of genotype x environmental interaction. Crop Science. 42(2):489-496.

7 Eberhart, S. T. and Russell, W. A. 1966. Stability parameters for comparing varieties 1. Crop Science. 6(1):36-40.

8 FAO. 2024. Food and Agriculture Organization of the United Nations. FAO Statistics. Rome, Italy. www.fao.org/statistics/es/.

9 García, M. P. J.; Pérez, A. I. B.; Prieto, R. G. P.; Medina, C. D. E.; Sánchez, D. M.; Marín, R. C. A. y Medina, H. A. E. 2021. Interacción genotipo ambiente y potencial productivo de 25 variedades de maíz amarillo en la provincial de Tayacaja, Perú. Bioagro. 33(2):67-69.

10 Gauch, H. G. and Zobel, R. W. 1988. Predictive and postdictive success of statistical analysis of yield trials. Theroretical and Applied Genetics. 76(1):1-10. https://doi.org/10.1007/BF00288824.

11 Kahn, M. M. H.; Rafii, M. Y.; Ramlee, S. I.; Jusoh, M. and Al Mamun, M. 2021. AMMI and GGE biplot analysis for yield performance and stability assessment of selected Bambara groundnut (*Vigna subterranean* L. Verdc) genotypes under the multi-environmental trails (METs). Scientific reports. 11(1):1-17. https://doi.org/10.1038/s41598-021-01411-2.

12 Liu, H.; Gan, W.; Rengel, Z. and Zhao, P. 2016. Effects of zinc fertilizer rate and application method on photosynthetic characteristics and grain yield of summer maize. Journal of Soil Science and Plant Nutrition. 16(2):550-562. http://dx.doi.org/10.4067/S0718-95162016005000045.

13 Luo, J.; Pan, Y. B.; Que, Y.; Zhang, H.; Grisham, M. P. and Xu, L. 2015. Biplot evaluation of test environments and identification of mega-environment for sugarcane cultivars in China. Sci Rep. 5(15505):1-11. https://doi.org/10.1038/srep15505.

14 Mehraj, U.; Abidi, I. and Ahmad, M. 2017. Stability analysis for physiological traits, grain yield and its attributing parameters in oats (*Avena sativa* L.) in the Kashmir Valley. Electronic Journal of Plant Breeding. 8(1):59-62.

15 Mühleisen, J.; Piepho, H. P.; Maurer, H. P.; Longin, C. F. H. and Reif, J. C. 2014. Yield stability of hybrids versus lines in wheat, barley and triticale. Theor Appl Genet. 127(2):309-316. https://doi.org/10.1007/s00122-013-2219-1.

16 Müller, C.; Elliott, J.; Pugh, T. A. M.; Ruane, A. C.; Ciais, P.; Balkovic, J.; Deryng, D.; Folberth, C.; Izauralde, R. C.; Jones, C. D.; Khabarov, N.; Lawrence, P.; Liu, W.; Reddy, A. D.; Schmid, E. and Wang, X. 2018. Global patterns of crop yield stability under additional nutrient and water inputs. PLos One. 13(6):1-14. https://doi.org/10.1371/journal.pone.0198748.

17 Mut, Z.; Akay, H. and Erbas Köse, Ö. D. 2018. Grain yield, quality traits and grain yield stability of local oat cultivars. Journal of soil science and plant nutrition. 18(1):269-281. http://dx.doi.org/10.4067/S0718-95162018005001001.

18 Reckling, M.; Ahrends, H.; Chen, T. W.; Eugster, W.; Hadasch, S.; Knapp, S.; Laidig, F.; Linstädter, A.; Macholdt, J.; Piepho, H. P.; Schiffers, K. and Döring, T. 2021. Methods of yield stability analysis in long-term field experiments. A review. Agron. Sustain. Dev. 41(27):1-28. https://doi.org/10.1007/s13593-021-00681-4.

19 Rodríguez, P. J. E.; Sahagún, C. J.; Villaseñor, M. H. E.; Molina, G. J. D. and Martínez, G. A. 2002. Estabilidad de siete variedades comerciales de trigo (*Triticum aestivum* L.) de temporal. Revista Fitotecnia Mexicana. 25(2):143-151.

20 SIAP. 2024. Sistema de Información Agroalimentaria y Pesquera. Panorama Agroalimentario 2024. http://www.siap.gob.mx.

DOI: https://doi.org/10.29312/remexca.v16i8.3940

21 Tigchelaar, M.; Battisti, D. S.; Naylor, R. L. and Ray, D. K. 2018. Future warming increases probability of globally synchronized maize production shocks. Proc Natl Acad Sci USA. 115(26):6644-6649. https://doi.org/10.1073/pnas.1718031115.

22 Vargas. H. M. y Crossa, J. F. 2000. El análisis AMMI y la gráfica del Biplot en SAS. Unidad de biometría. CIMMYT. México. 46 p. .

23 Villaseñor, M. H. E. y Espitia, R. E. 2000. Características de las áreas productivas de trigo de temporal: problemática y condiciones de producción. *In*: el trigo de temporal en México. Secretaría de Agricultura, Ganadería, Pesca y Alimentación, Instituto, Nacional de Investigaciones, Forestales (INIFAP), Agrícolas y Pecuarias (SAGARPA), Centro de Investigación del Centro, Campo Experimental Valle de México. Chapingo, Estado de México. 85-98 p.

24 Villaseñor, M. H. E.; Espitia, R. E.; Huerta, E. J.; Osorio, A. L.; Hortelano, S. R.; Martínez, C. E. and Rodríguez, G. M. F. 2018. Ágata: nueva variedad de avena (*Avena sativa* L.) para la producción de grano en México. Revista Mexicana de Ciencias Agrícolas. 9(5):1083-1088. https://doi.org/10.29312/remexca.v9i5.1512.

25 Villaseñor, M. H. E.; Huerta, E. J.; Rodríguez, G. M. F.; Hortelano, S. R. R.; Espitia, R. E. y Martínez, C. E. 2021. Mejoramiento genético de avena en México. Revista Mexicana de Ciencias Agrícolas. 12(25):21-25. https://doi.org/10.29312/remexca.v12i25.2808.

Grain yield stability of rainfed oat varieties in the High Valleys of Mexico

Journal Information
Journal ID (publisher-id): remexca
Title: Revista mexicana de ciencias agrícolas
Abbreviated Title: Rev. Mex. Cienc. Agríc
ISSN (print): 2007-0934
Publisher: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

Article/Issue Information
Date received: 1 September 2025
Date accepted: 1 November 2025
Publication date: 13 December 2025
Publication date: Nov-Dec 2025
Volume: 16
Issue: 8
Electronic Location Identifier: e3940
DOI: 10.29312/remexca.v16i8.3940

Categories

Subject: Articles

Keywords:

Keywords:

Avena sativa L.
genotype × environment interaction
rainfed environments
yield stability

Counts

Figures: 2
Tables: 3
Equations: 0
References: 25