Economic Viability of Organic Fertilization in Forage Oats (*Avena sativa* L.) in the Mexicali Valley

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ABSTRACT

Objective: To economically evaluate the use of chemical, organic and organic-mineral fertilizers in of forage oat production in the Mexicali Valley; and to determine the profitability of each fertilization type.

Design/methodology/approach: Three treatments were established, one chemically fertilized (T1), one with organic fertilization (T2), and one with organic-mineral fertilization (T3) with two replications under a completely randomized design. Cash flow, financial costs and economic costs were calculated.

Results: Fertilization costs accounted for between 37% and 52% of the cost structure. Treatments T2 and T3 did not cover production costs. Only treatment T1 treatment demonstrated the ability to cover both production and financial costs. None of the treatments covered economic costs.

Limitations on study/implications: It is suggested to replicate the economic viability analyses in consecutive productive cycles, as other studies have shown positive impacts on soil fertility.

Findings/conclusions: The organic and organic-mineral fertilization systems (T2 and T3) were not profitable in the short term. The chemical fertilization system (T1) demonstrated the ability to cover, in addition to production costs, the depreciation costs of fixed assets. However, none of the treatments showed the ability to compensate the risk of investing in the activity.

Keywords: profitability, production costs, financial costs, organic production.

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INTRODUCTION

Oats (*Avena sativa* L.) is a widely cultivated grass with the purpose of producing grain for human nutrition or forage for animal feed. In 2021, it ranked sixth in global cereal production, following maize (40.3%), rice (26.26%), wheat (25.7%), barley (4.8%), and sorghum (2%) (FAOSTAT, 2023). In Mexico, it stands out as a key input for livestock feed production; additionally, due to its wide range of adaptability in different production areas, it is considered a strategic crop (SAGARPA, 2017). In 2022, Chihuahua ranked

as the leading producer with 2.57 million tons (16%), followed by Durango (16.1%) and Zacatecas (18.1%); these states accounted for 50.3% of the national production (SIAP, 2024). Regarding oat crop yields, Baja California, Sonora, and Coahuila have shown the highest average yields in recent production cycles, with 38, 32, and 28 t ha^{-1}, respectively (SIAP, 2024).

On the other hand, the fertilizer market has experienced particular dynamics due to global events. One of the effects of the war between Russia and Ukraine has been the increase in the prices of cereals, energy, and fertilizers. An analysis conducted by the OECD and FAO (2022) estimates that for every 1% increase in fertilizer prices, agricultural commodity prices would rise by 0.2%. This increase in one of the most important components within the cost structure of most agricultural crops, combined with the inverse relationship between fertilizer use and its price (García-Salazar, Borja Bravo and Rodríguez-Licea, 2018), exacerbates concerns about agricultural productivity in the short term (OECD and FAO, 2022; United Nations, 2022). In the national context, the effects have been similar; in 2022, the value of Mexico's fertilizer imports increased by 75%, amounting to 3.513 billion dollars, while exports totaled 368.87 million dollars (International Trade Centre, 2023).

In addition to the above, there is an increasing challenge for agriculture to reduce its environmental footprint and increase food availability for the coming decades. In this regard, the use of organic fertilizers has demonstrated improvements in various soil fertility indicators, and combined fertilizations with chemical and organic fertilizers have proven to be a viable alternative for achieving optimal production levels (Montaño-Carrasco *et al.*, 2017). However, despite the growing importance of diversifying fertilization sources for agricultural crops, few studies have evaluated the economic profitability of using organic fertilization as an alternative for farmers. Consequently, the objective of this research was to economically evaluate the use of an organic fertilizer, a chemical fertilizer, an organic fertilizer, and an organic-mineral fertilizer in forage oat production in the Mexicali Valley, to determine the profitability of each type of fertilization.

MATERIALS AND METHODS

Location of the experiment

The experiment was conducted during the fall-winter cycle of 2021-2022 at the experimental station of the Institute of Agricultural Sciences of the Autonomous University of Baja California, located in Ejido Nuevo León, Mexicali, Baja California, Mexico, between the geographic coordinates 32° 24' north latitude and 115° 11' west longitude, at an altitude of 15 meters, in clay-textured soil. The climate in this area is classified as very dry and very hot to hot, with an average annual temperature of 22.3 °C, a maximum of 50 °C, and a minimum of 0 °C, and an average annual precipitation of 77.8 mm (CONAGUA, 2024; INEGI, 2017).

Treatments

Three treatments were established with two replicates under a completely randomized design, with the characteristics mentioned in Table 1.

Table 1. Characteristics of the treatments.

Treatments	Replicates	Area (ha)	Type of fertilization
T1	1	0.5	Chemical
T1	2	0.5	Chemical
T2	1	0.5	Organic
T2	2	0.5	Organic
T3	1	0.5	Organic and mineral
T3	2	0.5	Organic and mineral

Agronomic management of the crop

Soil preparation involved breaking and crossing with a disk plow, followed by leveling with a medium harrow. Planting was then carried out in November 2021 using a conservation tillage planter (model 205-13-2), equipped with 13 seed dispensing systems, with a row spacing of 17 cm. The oat variety sown was Bachíniva, with a seeding density of 120 kg ha^{-1}. Chemical fertilization was applied at the time of planting with a dose of 200 kg ha^{-1} of urea (46-00-00) and 50 kg ha^{-1} of MAP (11-52-00).

Organic and organic-mineral fertilization was applied using Mar y Tierra® products and involved the application of liquid fertilizers dissolved in 400 L of water, applied during the first irrigation with the following doses: organic 20 L ha^{-1} (10-20-1) and 20 L ha^{-1} (20-1-1), and organic-mineral 15 L ha^{-1} (4-6-1) and 15 L ha^{-1} (5-1-1). Four irrigations were carried out with an average interval of 29 days between them. The oat was harvested 120 days after sowing, when the grain was in the milk-dough stage (Servin *et al.*, 2018). Subsequently, a tractor with harrows was used to pile the product and allow it to lose moisture before being baled, with approximately 45 kg of dry oat straw per bale. The harvested oats were sold at the field for 180 MXN per bale, thus no distribution or marketing costs were incurred.

Economic Analysis

For each treatment, technical and economic information about the production cycle was recorded in an Excel® 2011 file, including dates and tasks for sowing, irrigation, fertilization, harvesting, input costs, labor, infrastructure, machinery and equipment, as well as their respective maintenance. With the technical parameters and production costs, the following variables were calculated and analyzed (AAEA, 2000; Sagarnaga Villegas, Salas González, and Aguilar Ávila, 2018):

$$TOC = FC + VC$$
$$NCF = FC + VC + Loans + With$$
$$FinC = FC + VC + Depreciation$$
$$ECc = FC + CV + Depreciation + OPc$$
$$TI = Q * P$$
$$NI = TI - ECc$$

Where: *TOC*=total operating costs; *FC*=fixed costs; *VC*=variable costs; *NCF*=net cash flow, *Loans*=payments on loans, *With*=withdrawals; *FinC*=financial costs; *ECc*=economic costs; *OPc*=opportunity cost. *TI*=Total Income; *Q*=quantity of bales produced; *SP*=Sale price per bale; *NI*=net income.

Since the cultural practices were carried out using the Institute's tractor and rented agricultural implements, the cash flow analysis included the rental cost of the implements, while the financial cost analysis considered the tractor depreciation as a fixed cost.

In addition, a cost for technical consulting was assigned to treatments T2 and T3; since, under organic fertilization conditions, the producer would need professional advice at least during the initial production cycles. In calculating the opportunity costs of the producer's work, the cost of normal labor was considered, and in the case of business management of the production unit, the cost of specialized labor was considered, which for the production process is the irrigation worker.

With the above information, the target yields were determined as described below:

Target Yield 1 (Y1): yield required to cover variable costs

$$S1 = \frac{VC}{P}$$

Where: *VC*=unit variable cost and *P*=sale price.

Thus, if S1>Y1, the company will be able to cover its variable costs; on the other hand, if S1<Y1, the company will not be able to cover its variable costs. Subsequent target yields are calculated similarly, adding the cost detailed below:

Target Yield 2 (Y2): yield required to cover Y1 plus fixed operating costs.

Target Yield 3 (Y3): yield required to cover Y2 plus depreciation.

Target Yield 4 (Y4): yield required to cover Y3 plus producer labor and business management.

Target Yield 5 (Y5): yield required to cover Y4 plus cost of capital.

Target Yield 6 (Y6): yield required to cover Y5 plus opportunity cost of the production factors.

Target Yield 7 (Y7): yield required to cover Y6 and obtain a return for the risk of investing in the activity.

RESULTS AND DISCUSSION

The treatment with the highest yield was the conventionally fertilized one, followed by the organic mineral and, finally, the organic fertilization, with averages of 4.05, 1.44, and 1.21 t ha^{-1}, respectively (Table 2). The yield of T1 was consistent with those obtained in previous studies (Espitia Rangel, Villaseñor Mir, Tovar Gómez, de la O Olán, and Limón Ortega, 2012; Gil Gil, Martínez Rueda, and Estrada Campuzano, 2014; Sosa-Montes *et al.*, 2020), where yields between 2.5 and 8 t of dry matter ha^{-1} were reported with different

Table 2. Obtained yields.

Treatments	Replicates	Type of fertilization	Yield	
			(oat bales ha^{-1})	(t ha^{-1})
T1	1	Chemical	88	3.96
T1	2	Chemical	92	4.14
T2	1	Organic	18	0.81
T2	2	Organic	36	1.62
T3	1	Organic and mineral	32	1.44
T3	2	Organic and mineral	32	1.44

varieties, chemical fertilization rates, and production systems. Meanwhile, SIAP (2024) reported a national average yield of 3.63 t of dry matter ha^{-1} for 2022.

On the other hand, the yields of treatments T2 and T3 compared to T1 are similar to studies such as Montaño-Carrasco *et al.* (2017), who reported higher yields in treatments fertilized with chemical sources (12.3 t of dry matter ha^{-1}) compared to those fertilized with organic sources (6.3 and 2.5 t of dry matter ha^{-1}). It is worth mentioning that the authors found that the best response in leaf nutrient content was obtained with chemical applications and their combination with an organic fertilizer. Additionally, the incorporation of organic fertilizers or their combination with chemical fertilizers positively impacts soil fertility parameters, results that may not necessarily be reflected in the yield of the first production cycle (Ibarra-Villarreal *et al.*, 2020). In this regard, Rodríguez-Herrera *et al.* (2020) found that the yield of grain oats planted for two consecutive cycles under organic fertilization increased by 14.4% in the second year.

Economic Analysis

Agronomic management showed no differences between replicates, so Table 3 presents the production cost structure by treatment. It can be observed that fertilization was the most significant item, representing between 22% and 52%, followed by planting and irrigation.

Table 3. Production Cost Structure (MXN ha^{-1}).

Concept	T1	T2	T3
Variable costs	11,898	9,119	8,286
Soil preparation	960	960	960
Sowing	2,376	2,376	2,376
Irrigation	1,500	1,500	1,500
Fertilization	6,300	2,732	1,899
Harvest	763	763	763
Technical assistant	0	789	789
Fixed costs	329	329	329
Agricultural machinery maintenance	329	329	329
Total operating costs	12,227	9,448	8,615

For the calculation of the cash flow in this research, only fixed and variable costs were considered, as no credit payments or cash withdrawals were made. These costs are those that a producer typically incurs during the production cycle and are generally the only items considered to determine whether their activity is profitable or not (Table 4).

From the cash flow analysis, only treatment T1 proved to be profitable in the short term, as reported by most studies on production costs in the agricultural sector (Aguilar Ávila, Sagarnaga Villegas, Salas González, & Arroyo Pozos, 2019, 2022; Delgadillo-Ruiz, Leos-Rodríguez, Valdez-Cepeda, Ramírez-Moreno, & Salas-González, 2016; Domínguez-García, Granados-Sánchez, Sagarnaga-Villegas, Salas-González, & Aguilar-Ávila, 2017). In this regard, producers who wish to implement organic fertilization under the conditions of this study will face liquidity problems in the short term; that is, within the same production cycle, they will not be able to cover production costs with the expected income.

In addition to the out-of-pocket costs, other costs must be considered to determine if the activity is profitable in the medium term. Therefore, in this study, depreciation was included as a fixed cost in the financial analysis. Under this premise, treatment T1 remains profitable (Table 4). That is, a producer applying chemical fertilization under the conditions of this experiment will be able to cover the replacement of the machinery and equipment needed for the operations.

Finally, the opportunity cost of production factors, which is reflected in the economic cost, should also be considered. The current analysis demonstrated that in the long term, none of the treatments are profitable and do not provide a return on the risk of investing in this activity (Sagarnaga Villegas *et al.*, 2018) (Table 4).

Several economic analyses demonstrate that few agricultural activities are profitable under economic analysis (Aguilar Ávila *et al.*, 2019, 2022; Domínguez-García *et al.*, 2017). Generally, these are production units with several years of experience and a certain size that allows them to benefit from economies of scale.

Table 4. Economic analysis (MXN ha^{-1}).

Concept	T1	T2	T3
Variable costs	11,898	9,119	8,286
Fixed costs	924	924	924
Opportunity cost	6,304	6,269	6,255
Opportunity cost of the land	5,000	5,000	5,000
Opportunity costs of the working capital	247	212	198
Opportunity costs of the producer labor	564	564	564
Opportunity costs of the business management	493	493	493
Total income (pesos ha^{-1})	16,200	4,860	5,760
Cash flow	12,227	9,448	8,615
Financial cost	12,822	10,043	9,210
Economic cost	19,126	16,273	15,423
Net income (MXN ha^{-1})	−2,926	−11,413	−9,663
Net income (MXN oat $bale^{-1}$)	−33	−423	−302

Target Yields

Considering the selling price of 180 pesos per bale, the different treatments should achieve the yields outlined in Table 5 to cover their respective costs. Ideally, production units should aim to produce at least the Target Yield 7, as it ensures coverage of economic costs and provides a return on the risk associated with engaging in this activity.

Table 5. Target Yields (t ha^{-1}).

Target yield	Description	Treatments		
		T1	T2	T3
	Obtained yield	4.05	1.21	1.44
1	Cover variable costs	2.97	2.28	2.07
2	Cover Y1 plus fixed operating costs	3.06	2.36	2.15
3	Cover Y2 plus depreciation	3.21	2.51	2.30
4	Cover Y3 plus producer labor and business management	3.47	2.78	2.57
5	Cover Y4 plus cost of capital	3.53	2.82	2.61
6	Cover Y5 plus opportunity cost of the production factors	4.78	4.07	3.86
7	Cover Y6 and obtain a return for the risk of investing in the activity	4.83	4.11	3.90

CONCLUSIONS

The treatment with chemical fertilization (T1) showed higher yields compared to the treatments fertilized with organic and organic-mineral methods (T2 and T3). Furthermore, in the cash flow analysis, only the T1 treatment demonstrated the ability to cover production costs.

In the financial analysis, treatment T1 remained viable, indicating that this system is profitable in the medium term, as it covered not only production costs but also the depreciation costs of fixed assets. However, when the opportunity costs of production factors are also considered, none of the treatments proved to be economically viable. Since fertilization was one of the major cost components in the production cost structure (between 22% and 52%), any change in the price of this input represents a sensitive aspect for production units. Therefore, it is suggested to conduct financial and economic viability analyses in consecutive production cycles, once other studies have demonstrated positive impacts on soil fertility.

REFERENCES

FAOSTAT. (2023). Datos sobre alimentación y agricultura. Recuperado el 12 de junio de 2023, de https://www.fao.org/faostat/es/#home

SAGARPA. (2017). Planeación Agrícola Nacional 2017-2030. Ciudad de México. Recuperado de https://www.gob.mx/agricultura/acciones-y-programas/planeacion-agricola-nacional-2017-2030-126813

SIAP. (2024). Anuario estadístico de la producción agrícola. Recuperado el 26 de marzo de 2024 de https://nube.siap.gob.mx/cierreagricola/

OECD y FAO. (2022). OCDE-FAO Perspectivas agrícolas 2022-2031. Paris: OECD. https://doi.org/10.1787/820ef1bb-es

García-Salazar, J. A., Borja Bravo, M. y Rodríguez-Licea, G. (2018). Consumo de fertilizantes en el sector agrícola de México: un estudio sobre los factores que afectan la tasa de adopción. *Interciencia, 43*(7), 505-510.

United Nations. (2022). Global impact of war in Ukraine on food energy and finance systems. Recuperado de https://unsdg.un.org/resources/global-impact-war-ukraine-food-energy-and-finance-systems-brief-no2

International Trade Centre. (2023). Trade Map. Recuperado el 29 de julio de 2023 de https://www.trademap.org/Index.aspx?nvpm=3%7c%7c%7c%7c%7c%7c%7c%7c%7c%7c%7c%7c%7c%7c%7c%7c%7c&lang=es

Montaño-Carrasco, M., Hernández-Rodríguez, A., Martínez-Rosales, A., Ojeda-Barrios, D., Núñez-Barrios, A. y Guerrero-Prieto, V. (2017). Producción y contenido nutrimental en avena forrajera fertilizada con fuentes químicas y orgánicas. *Revista Fitotecnia Mexicana, 40*(3), 317-324.

CONAGUA. (2024). Actualización de la disponibilidad media anual de agua en el acuífero Valle de Mexicali (0210), Estado de Baja California. Ciudad de México.

INEGI. (2017). Anuario estadístico y geográfico de Baja California 2017. México. Recuperado de www.inegi.org.mx

Servín Palestina, M., Sánchez Gutiérrez, R. A., Ramírez Valle, O., Galindo Reyes, M. A., y Gutiérrez Bañuelos, H. (2018). Modelos para programación y optimización de agua de riego en avena forrajera. *Revista Mexicana de Ciencias Pecuarias, 9*(4), 667-684.

AAEA. (2000). Commodity costs and returns estimation handbook. Ames, Iowa. Recuperado de http://ageconsearch.umn.edu

Sagarnaga Villegas, L. M., Salas González, J. M. y Aguilar Ávila, J. (2018). Metodología para estimar costos, ingresos y viabilidad financiera y económica en unidades representativas de producción (1ed.). Chapingo, México: Universidad Autónoma Chapingo (UACh), Centro de Investigaciones Económicas, Sociales y Tecnológicas de la Agroindustria y la Agricultura Mundial (CIESTAAM).

Espitia Rangel, E., Villaseñor Mir, H. E., Tovar Gómez, R., de la O Olán, M. y Limón Ortega, A. (2012). Momento óptimo de corte para rendimiento y calidad de variedades de avena forrajera. *Revista Mexicana de Ciencias Agrícolas, 3*(4), 771-783.

Gil Gil, H., Martínez Rueda, C. G. y Estrada Campuzano, G. (2014). Impacto del sistema de labranza y dosis de nitrógeno en el rendimiento y calidad nutricional de forraje de avena. *Revista Mexicana de Ciencias Agrícolas, 5*(6), 951-964.

Sosa-Montes, E., Pedroza Mendoza, S. I., Alejos de La Fuente, J. I., Villarreal González, J. A., Velasco Estrada, D. B., & Rodríguez Rosales, E. (2020). Rendimiento de forraje de avena variedad Chihuahua. *Revista Mexicana de Ciencias Agrícolas, 14*(24), 255-264.

Ibarra-Villarreal, A. L., Parra-Cota, F. I., Yepez, E. A., Gutiérrez-Coronado, M. A., Valdez-Torres, L. C. y de los Santos-Villalobos, S. (2020). Impact of a shift from conventional to organic wheat farming on soil cultivable fungal communities in the Yaqui Valley, Mexico. *Agrociencia, 54*(5), 643-659.

Rodríguez-Herrera, S. A., Salgado-Ramírez, O., García-Rodríguez, J. G., Cervantes-Ortiz, F., Figueroa-Rivera, M. G. y Mendoza-Elos, M. (2020). Chemical and organic fertilization in oats: Seed yield and quality. *Agronomía Mesoamericana, 31*(3), 567-579. https://doi.org/10.15517/AM.V31I3.39184

Aguilar Ávila, J., Sagarnaga Villegas, L. M., Salas González, J. M. y Arroyo Pozos, M. G. (2019). Ingresos y costos de producción 2013-2015. Unidades representativas de producción agropecuaria. Chapingo, México: Universidad Autónoma Chapingo, CIESTAAM.

Aguilar Ávila, J., Sagarnaga Villegas, L. M., Salas González, J. M. y Arroyo Pozos, M. G. (2022). Ingresos y costos de producción 2013-2015. Unidades representativas de producción agropecuaria. Primera adenda: principales resultados 2016-2017. Chapingo, México: Universidad Autónoma Chapingo.

Delgadillo-Ruiz, O., Leos-Rodríguez, J. A., Valdez-Cepeda, R. D., Ramírez-Moreno, P. P. y Salas-González, J. M. (2016). Análisis de la viabilidad de la producción de frijol (*Phaseolus vulgaris* L.) en el largo plazo en Zacatecas, México. *Agroproductividad*, 9(5), 16-21.

Domínguez-García, I. A., Granados-Sánchez, M. del R., Sagarnaga-Villegas, L. M., Salas-González, J. M. y Aguilar-Ávila, J. (2017). Viabilidad económica y financiera de nopal tuna (*Opuntia ficus-indica*) en Nopaltepec, Estado de México. *Revista Mexicana de Ciencias Agrícolas, 8*(6), 1371-1382.