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Effect of doses of chicken manure compost and raw chicken manure on organic wheat yield and soil variables

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Abstract

In the Yaqui Valley, Sonora, Mexico, application doses of 0, 7.5, and 15 t ha^{-1} of raw and composted chicken manure were evaluated in organic wheat. Yields were 6.318, 6.755, and 7.055 t ha^{-1} with compost, and 6.462, 6.771, and 7.327 t ha^{-1} with raw chicken manure. Prior to planting, soil values were 89 kg ha^{-1} of $N–NO_3$, 62.9 ppm P, 1.41% organic matter (OM), 1.26 cm h^{-1} hydraulic conductivity (HC), 2.65 dS m^{-1} electrical conductivity (EC), and pH 8.23. After harvest, with compost, $N–NO_3$ levels were 24, 34, and 50 kg ha^{-1}; phosphorus 37, 41, and 48 ppm; OM 1.28, 1.25, and 1.53%; HC 1.82, 1.80, and 1.53 cm h^{-1}; EC 3.20, 3.67, and 4.22 dS m^{-1}; and pH 8.62, 8.57, and 8.50. With raw chicken manure, $N–NO_3$ was 46, 47, and 64 kg ha^{-1}; P 60, 67, and 71 ppm; OM 1.42, 1.45, and 1.52%; HC 3.83, 3.69, and 3.95 cm h^{-1}; EC 3.71, 3.42, and 3.24 dS m^{-1}; and pH 8.43, 8.46, and 8.39. Both amendments improved the chemical and physical properties of the soil. Compost produced more consistent and significant effects, making it a more stable option; raw chicken manure is economical, but its variability limits the consistency of the results. In both cases, it is necessary to monitor soil salinity to avoid adverse effects and optimize their use within sustainable agricultural systems.

Keywords: Chicken manure; Compost; Organic agriculture; Wheat yield; Salinity

1 Introduction

Currently, organic agriculture is practiced in 188 countries, covering more than 96 million hectares and involving at least 4.5 million farmers. The countries with the largest areas of organic production in 2022 were Australia, India, and Argentina, with 53, 4.7, and 4.1 million hectares, respectively. In this context, Mexico ranks 22nd in terms of area dedicated to organic production, with 432,141 hectares managed by 54,638 producers. Compared to 2021, Mexico was the fifth country reporting the largest increase in organic area, adding 194,066 hectares. In addition to certified organic area, Mexico has 270,026 hectares of wild collection and 5,568 hectares dedicated to beekeeping, totaling 448,185 hives [1]. For 2023, 108 organic crops are produced in Mexico, with coffee, avocado, banana, and mango standing out in terms of cultivated area [2]. Organic agriculture was practiced by our ancestors and maintained by small-scale farmers, achieving a balance with their environment through the sustainable use of resources. Over the years, global population growth has necessitated an increase in food production and expansion of cultivated areas. Today, the trend is to return to sustainable resource use, and the application of organic fertilizers is considered a viable strategy to achieve this [3]. By incorporating organic amendments, agricultural soils can maintain or improve fertility while reducing negative environmental impacts [4]. Among the organic amendments used in organic agriculture, chicken manure stands out for its high concentration of essential nutrients and its capacity to improve soil fertility [5]. Worldwide, various studies have evaluated the use of chicken manure and compost in crop production. For example, the application of chicken-manure-derived fertilizer in wheat has shown positive effects on yield components and seed quality [6]. In a recent

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study, variable doses of organic fertilizer based on chicken manure significantly increased plant height, spike length, and thousand-grain weight in spring wheat [7]. Furthermore, combining poultry manure with cereal straw has been used in composting processes to improve the stability and maturity of the final product [8].

In Mexico, organic agriculture has also been gaining ground. According to reports, the Yaqui Valley in Sonora has certified organic activity, albeit in an early stage, where various manures have been identified as valuable fertilizer sources, with chicken manure being particularly notable [9]. An organic fertilization study in potato evaluated three levels of chicken manure and found improvements in yield, demonstrating the agronomic potential of this fertilizer in Mexican contexts [10]. Additionally, research on managing poultry waste through composting in Mexico has focused on transforming chicken manure into a more stable and safe amendment, preventing issues such as phytotoxicity during application [11]. In the state of Sonora, the promotion of organic wheat has been recognized as a strategy to produce chemical-residue-free food and maintain soil fertility [12]. This crop is particularly important in the Yaqui Valley, a region with a long-standing wheat-growing tradition and significance for national production [13]. The use of chicken manure in this context can contribute not only to organic soil fertility but also to the local circular economy and the sustainability of the agricultural system. The National Institute of Forestry, Agriculture, and Livestock Research (INIFAP) has promoted the use of chicken manure for soil conservation in the region, highlighting its potential to reverse soil degradation [14].

Although studies exist on the application of raw chicken manure and its advantages, it is also essential to consider its composted form. Composting improves material stability, reduces pathogen presence, and facilitates a more gradual supply of nutrients to the soil [15]. Several studies have shown that composting stabilizes organic matter and significantly reduces harmful microbial load and antimicrobial residues in chicken manure, lowering the risk of soil contamination and crop residue accumulation [16, 17]. During composting, essential nutrients are mineralized, the C/N ratio is improved, and nitrogen and phosphorus become more stable and available, contributing to a slower and more efficient nutrient release in the soil [18, 19].

Both raw chicken manure and chicken-manure compost offer numerous advantages for organic agriculture; however, it is crucial to establish appropriate doses and conduct a cost–benefit analysis to determine the most efficient option. Therefore, the objective of the present study was to evaluate the effect of three doses of chicken-manure compost and three doses of raw chicken manure on the yield of organic wheat and soil variables in the Yaqui Valley, Sonora, Mexico.

2 Material and methods

The study was conducted at the Norman E. Borlaug Experimental Field (CENEB) of the National Institute of Forestry, Agriculture, and Livestock Research (INIFAP), located in Block 910 of the Yaqui Valley, Sonora, at 109°55′31.07″ W and 27°22′06.41″ N, at an altitude of 38 m above sea level. The evaluation was carried out on a field under organic management since June 2017. The field was prepared with two passes of a harrow, leveling, and furrowing at 0.80 m spacing. A pre-sowing irrigation was applied on November 8, 2023. After the pre-sowing irrigation, three treatments of chicken-manure compost and raw chicken manure (0, 7.5, and 15 t ha^{-1}) were applied. Application was done by broadcasting, and the amendments were incorporated during the seedbed preparation for sowing.

Figure 1 Growth appearance of Noroeste C2021 wheat at 112 days after sowing under organic fertilization. Left: plots fertilized with variable doses of chicken-manure compost (0, 7.5, and 15 t ha^{-1}). Right: plots fertilized with variable doses of raw chicken manure (0, 7.5, and 15 t ha^{-1}).

Table 1 describes the chemical composition of Compost Plus chicken-manure compost [20]. For raw chicken manure, the Soil and Plant Nutrition Laboratory of CENEB-INIFAP reported total nitrogen and phosphorus contents of 2.25% and 1.85%, respectively. The commercial wheat variety Noroeste C2021 [21] was sown on November 29, 2023, at a seeding rate of 65 kg ha^{-1}. Four supplementary irrigations were applied to the chicken-manure compost treatments and three to the raw chicken manure treatments. Crop phytosanitary management included one application against aphids, one tractor-based cultivation, and two manual weedings. The experimental design was a randomized complete block with four replications. The experimental unit consisted of eight rows, each 115 m long and spaced 0.80 m apart, while the usable plot consisted of two rows, each three meters long with 0.80 m between rows. Harvest was performed manually with a sickle. Collected samples were threshed using a stationary Pullman-type thresher. The grain was cleaned to remove straw and glume residues, weighed, and its moisture content determined. The effect of 0, 7.5, and 15 t ha^{-1} of chicken-manure compost and raw chicken manure on wheat grain yield was evaluated at 12% moisture content.

Table 1 Guaranteed minimum composition of major and minor elements, fungi, and bacteria contained in the organic product Compost Plus.

Composition Guarantee	**Contents**
Nitrogen %	2-3
Phosphorus %	2-3
Potassium %	2-3
Sulfur %	0.5-1.5
Calcium %	6-8
Magnesium %	1-1.6
Iron %	0.4-1
Zinc ppm	400-700
Copper ppm	60-90
Manganese ppm	450-800
Boron ppm	40-100
Organic Matter %	40-45
Organic Carbon %	21-28

As part of the study, soil samples obtained at a depth of 0-30 cm before and after wheat cultivation were analyzed. These samples were collected in October 2023 and July 2024, respectively. Subsequently, the samples were tranported to the

Soil and Plant Nutrition Laboratory of CENEB-INIFAP for preparation and analysis. For the pre-cultivation samples, the soil was sampled at a depth of 0-30 cm along the experimental plot. Every 25 meters, a composite sample of two subsamples was collected, resulting in a total of four soil samples. For the post-cultivation samples, a composite sample of two subsamples was collected for each treatment. With three treatments (0, 7.5, and 15 t ha-1) and four replicates, a total of 12 samples were obtained in the chicken manure compost experiment and 12 samples in the raw chicken manure experiment.

The following variables were evaluated: nitrate nitrogen ($N\text{-}NO_3$, kg ha^{-1}), available phosphorus (available P, ppm), organic matter (OM, %), hydraulic conductivity (HC, cm h^{-1}), electrical conductivity (EC, dS m^{-1}), and pH in water. All determinations, except for electrical conductivity, were performed according to the procedures established in the Mexican Official Standard NOM-021-RECNAT-2000, which establishes the specifications for soil fertility, salinity, and classification [21]. Electrical conductivity was determined using a water:soil ratio of 2:1 (two parts water to one part soil). Measuring EC in diluted extracts is a common procedure in routine analysis due to its speed and high correlation with the EC obtained in the saturation extract. [22,23,24].

3 Results and discussion

The statistical analysis of the results reported significant differences ($P < 0.05$) between the 0 and 15 t ha^{-1} doses of chicken-manure compost, while no significant differences were observed for raw chicken manure ($P > 0.05$). The average grain yield values according to chicken-manure compost and raw chicken manure doses are presented in Figure 2. Wheat yield increased with higher doses. The difference between 0 and 7.5 t ha^{-1} was 437 kg ha^{-1}, and between 7.5 and 15 t ha^{-1} it was 300 kg ha^{-1}. A similar trend was observed with raw chicken manure; higher doses of the amendment led to increased wheat yield, with an increase of 309 kg ha^{-1} between 0 and 7.5 t ha^{-1} and 466 kg ha^{-1} between 7.5 and 15 t ha^{-1}. (Figure 2).

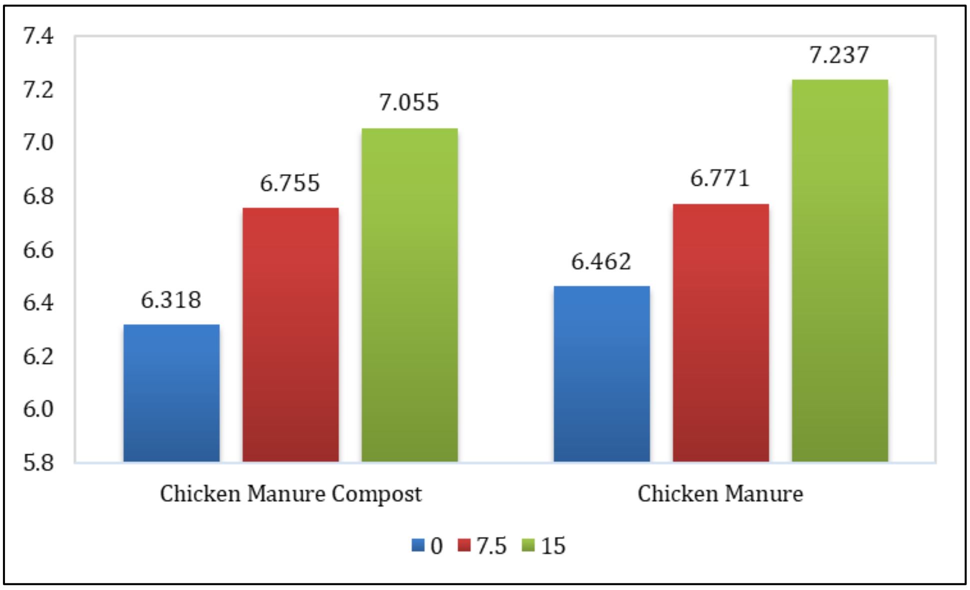

Figure 2 Effect of chicken-manure compost and raw chicken manure application dose (0, 7.5, and 15 t ha^{-1}) on wheat grain yield at 12% moisture content. Results correspond to trials conducted at CENEB–INIFAP during the Fall–Winter 2023/2024 cycle

The results indicate that both organic amendments improved yield compared with the control; however, statistical significance was observed only for compost (0 vs. 15 t ha^{-1}). This may be attributed to several factors:

Compost provides greater nitrogen stability and lower risk of losses through volatilization or other processes, improving its efficiency as a nutrient source. Recent studies have shown that chicken manure application can enhance soil fertility, but its mineralization may cause nitrogen losses if not managed properly [25].

Transforming chicken manure into compost contributes to organic matter stabilization, improved soil structure, and more gradual nutrient release. A recent study reported that composting chicken manure with biochar significantly increased soil fertility and improved beneficial microbial communities, suggesting more persistent soil enhancement when using well-produced compost [26].

Raw chicken manure, although nutrient-rich—with a total nitrogen content of 2.25% (similar to compost, 2–3%)—may release nutrients irregularly, resulting in losses (ammonia volatilization, leaching, salt accumulation, etc.) and lower plant nutrient-use efficiency. This issue is well documented in the literature, which warns of salinity risks or salt buildup when untreated manures are used, particularly in fine-textured soils or soils with poor drainage [27, 28].

Compost also enhances soil organic matter, moisture retention, microbial activity, and prolonged nutrient availability, all of which are key factors for sustainable nutrition and yield stability [29].

Therefore, although both amendments increased yield, compost appears to offer an advantage in terms of agronomic efficiency and stability, as reflected in the statistically significant differences. These findings agree with previous studies reporting cereal yield improvements with chicken manure, yet they emphasize the importance of composting or adequately treating the manure to optimize its benefits [26, 30].

Regarding soil analyses, the average values of the samples collected before planting were: 89 kg ha^{-1} $N–NO_3$, 62.9 ppm P, 1.41% OM, hydraulic conductivity of 1.26 cm h^{-1}, electrical conductivity of 2.65 dS m^{-1}, and pH of 8.23. Post-harvest soil analysis results are presented in Figures 3 and 4.

Application of chicken-manure compost resulted in statistically significant differences ($p < 0.05$) among fertilization doses for nitrate nitrogen and available phosphorus; higher compost doses corresponded to higher concentrations of these nutrients in the soil. The remaining variables showed no statistical differences (Figure 3). For the application of 0, 7.5, and 15 t ha^{-1} of raw chicken manure, $N–NO_3$, available P, OM, and HC tended to increase as the fertilization dose increased, while EC and pH tended to decrease. However, none of these variables showed statistically significant differences (Figure 4).

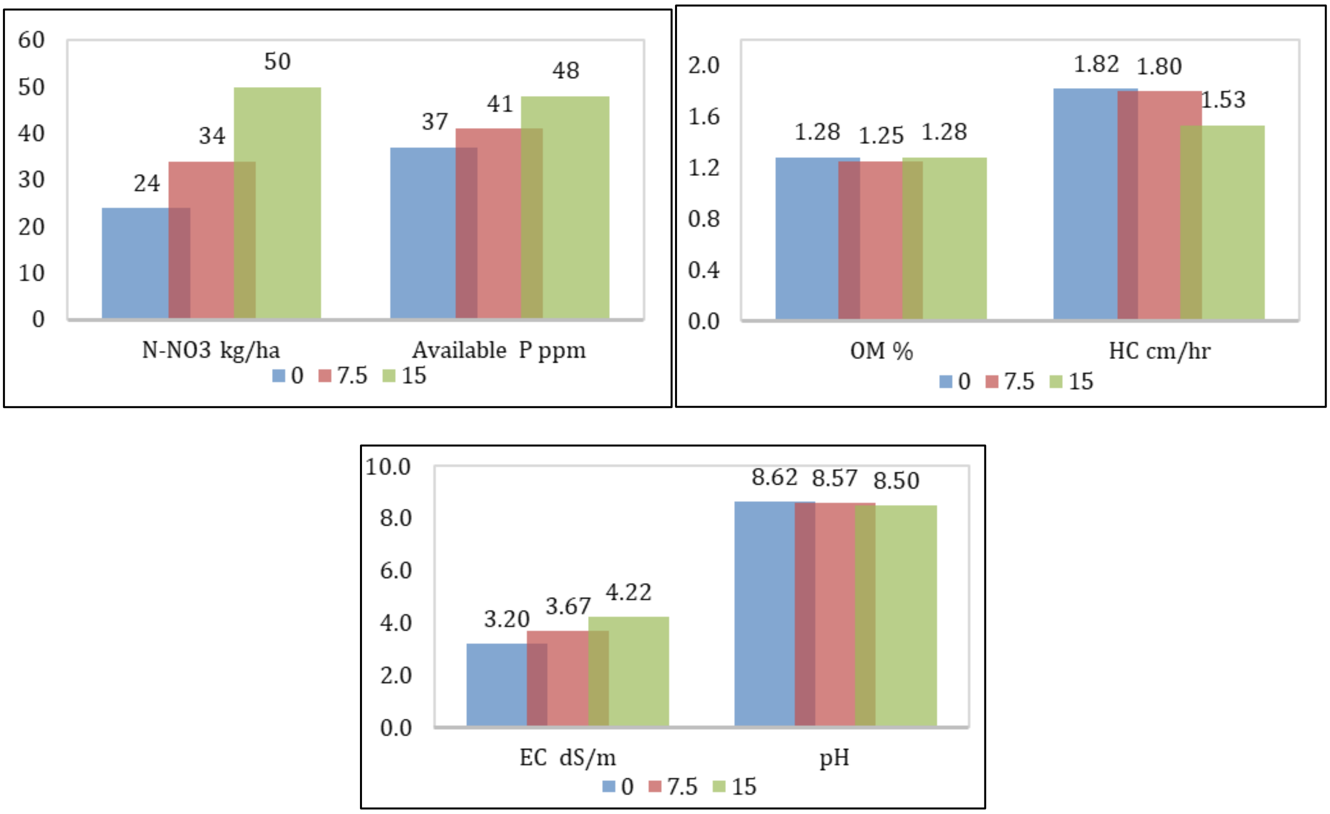

Figure 3 Dosage of chicken manure compost and soil variables after application. Top left: nitrate nitrogen (N-NO3, Kg ha-1) and available phosphorus (Phosphorus available, ppm); top right: organic matter (OM, %) and hydraulic conductivity (HC, cm hr-1); bottom center: electrical conductivity (EC, dS m-1) and pH in water. CENEB-INIFAP, Fall-Winter Cycle 2023/2024.

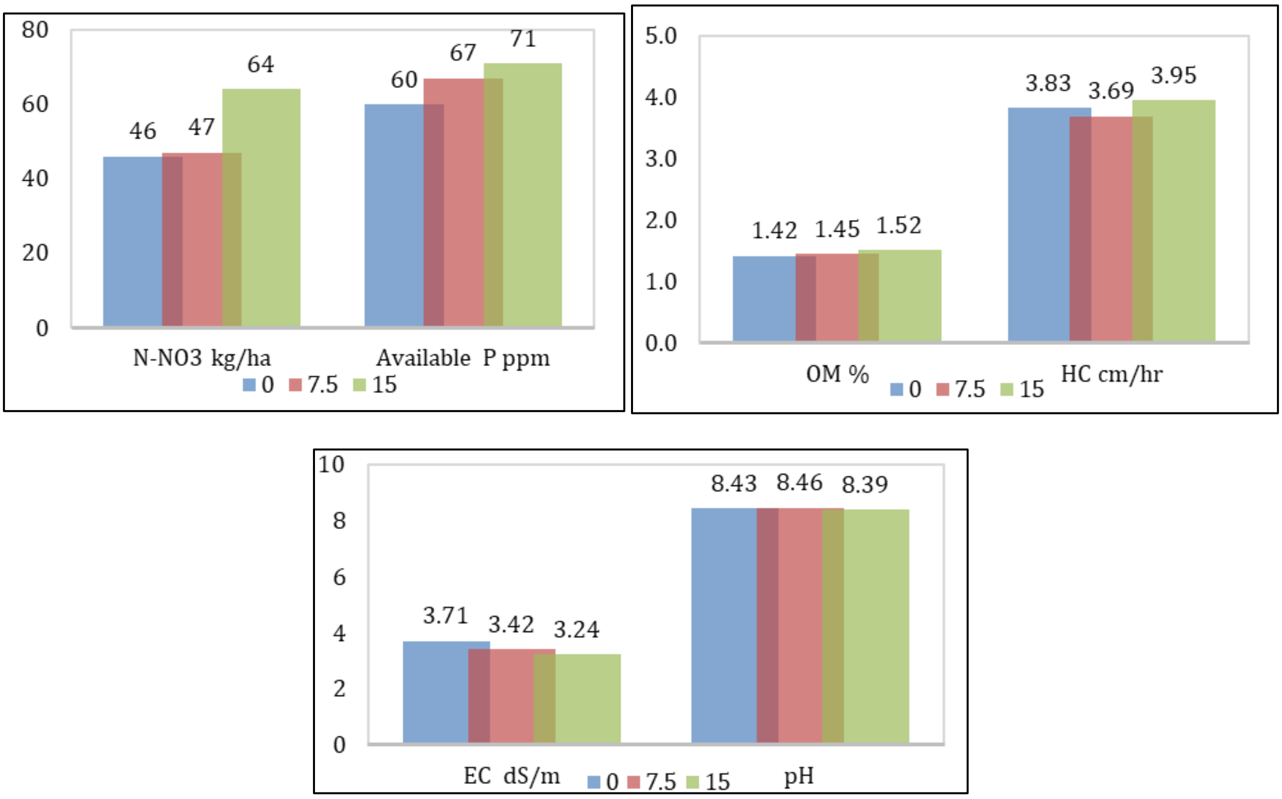

Figure 4 Dosage of raw chicken manure and soil variables after application. Top left: nitrate nitrogen (N-NO3, kg ha^{-1}) and available phosphorus (Phosphorus available, ppm); top right: organic matter (OM, %) and hydraulic conductivity (HC, cm hr^{-1}); bottom center: electrical conductivity (EC, dS m^{-1}) and pH in water. CENEB-INIFAP, Fall-Winter Cycle 2023/2024.

The results obtained show that the application of amendments with chicken manure, both composted and raw, significantly modified the chemical and physical properties of the soil compared with the pre-crop values. These changes coincide with what has been reported in multiple studies showing improvements in fertility, organic matter, and nutrient availability following the application of poultry manure [31, 32, and 33].

The higher concentrations of nitrate nitrogen ($N–NO_3$) and available phosphorus in the chicken-manure treatments agree with previous studies reporting substantial increases in N and P after organic amendments [31, 34]. The observed increase in organic matter (OM) is also consistent with the role of chicken manure as a source of organic carbon, enriching the soil organic fraction and contributing to nutrient retention [32, 35].

The increase in available phosphorus enhances the supply of this essential nutrient for crops, which is consistent with observations in soils treated with poultry manure [34]. Since agricultural soils often have low levels of available phosphorus, chicken manure can represent a viable alternative for improving fertility in low-input production systems.

Hydraulic conductivity (HC) increased following chicken-manure application, suggesting that the addition of organic matter and improvements in soil structure favored porosity, macroporosity, and water infiltration. This result aligns with findings in soils amended with poultry manure, where improvements in aggregation, structure, and water retention capacity have been reported [31, 36]. Improved soil physical structure allows better drainage and movement of air and water, benefiting root growth and biological activity.

Electrical conductivity (EC) increased with the dose of both raw and composted chicken manure. This is consistent with several studies showing that poultry manure applications increase soluble salts in the soil, raising EC proportionally to the dose applied [31, 34, and 37]. The increase in EC is not necessarily negative especially when the amendment supplies essential nutrients but it must be managed carefully, as excessive salinity can affect germination, plant growth, and water availability. In this regard, authors such as Watanabe et al. [38] found that high rates of chicken manure reduced seedling emergence and growth, correlating with increased soil salinity. The dose-response relationship observed in the present study (higher EC with higher chicken-manure doses) agrees with a recent greenhouse experiment in which increasing rates of poultry manure progressively increased soil EC, highlighting the need to adjust the dose according to the context, soil type, and crop requirements [34, 35].

Soil pH showed slight variations with chicken-manure application. Several studies indicate that chicken manure may cause modest increases or stabilization of pH due to its content of exchangeable bases and the release of cations during decomposition [16]. In calcareous or alkaline soils, such an increase may not be problematic, although monitoring pH together with EC is advisable to avoid adverse effects from salinity.

The results suggest that applying chicken manure, whether composted or raw, can improve soil fertility and structure by increasing essential nutrients (N and P), organic matter, and hydraulic conductivity, which could translate into improved crop yield. However, the increase in EC requires careful management: moderate doses, adequate drainage, and continuous monitoring of salinity to avoid negative effects. Recent studies recommend optimizing poultry-manure application rates according to soil characteristics and crop requirements, and in some cases combining organic amendments with leaching practices or complementary amendments to mitigate salt accumulation [28, 39]. Fractionated applications or alternating with other organic materials have also been suggested to maintain an acceptable long-term salt load [39].

In southern Sonora, the usefulness of manure as a soil improver and organic fertilizer is well recognized by farmers, who have rapidly adopted this technology to the extent of utilizing all available resources, both directly from poultry or livestock operations and in the form of compost certified by OMRI and COFEPRIS. The current price of raw chicken manure is 561 pesos per ton, and that of composted chicken manure is 1,200 pesos per ton. Raw chicken manure is the least expensive input; however, it did not show statistically significant differences compared with the control, implying that variability may be high and the additional yield not necessarily reproducible. In contrast, compost showed a significant increase providing greater reliability although at a higher cost. If the objective is to maximize yield with lower risk and to improve soil fertility, compost may be a more stable, although more expensive, option. If the goal is to reduce input costs and there is certainty of adequate nutrient management, raw chicken manure could be advantageous.

4 Conclusion

Chicken manure, both raw and composted, represents a viable alternative for improving soil fertility and increasing organic wheat yield in the Yaqui Valley, Sonora, Mexico. However, composted chicken manure provides a more stable and statistically significant response, associated with improved nutrient release and lower risk of losses or negative effects. Although its cost is higher, it offers greater agronomic reliability. Raw chicken manure is a more economical option, but its variability limits the consistency of results. In both cases, monitoring soil salinity is essential to avoid adverse effects and to optimize the use of these amendments within sustainable agricultural systems.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that No conflict of interest.

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