SEVEN publicações acadêmicas

Use of organominerals in agriculture

Crossref doi
https://doi.org/10.56238/sevened2023.001-018

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ABSTRACT
Animal production systems generate a high amount of organic waste, which if disposed of irrationally can cause contamination of both soil and water. Aviary litter is one of these examples, which, due to the high amount of organic matter and nutrients, has the potential to be applied as an organic fertilizer, totally or partially replacing chemical fertilizers, which are essential for plant development. The use of organic fertilizers can also reduce fertilization costs, which are high, mainly due to dependence on imports. Treatments such as composting are important to reduce the pathogenic load of the material, ensuring greater safety in its use. Many positive responses have already been scientifically proven, bringing benefits such as soil improvement and increased yields, both of annual crops and perennial pastures. The recommendation of the dose of the organic fertilizer can be carried out in order to meet the demand for P, which is found in low concentrations in Brazilian soils. To increase the concentration of nutrients in organic fertilizers and make them more balanced, they can be complemented with chemical fertilizers, generating organominerals. The proper use of residues, especially poultry litter, combined with chemical fertilizers can contribute satisfactorily to farmers, due to the possibility of reducing the operational cost of production and chemical fertilizers.

Keywords: Aviary litter, Phosphorus, Organic fertilization.

1 INTRODUCTION

Activities related to food production are in broad development in Brazil, with emphasis on poultry farming. This chain provides numerous benefits, being the promoter of various jobs, food, among other advantages for the region. However, this high production generates waste with a high pollutant load, which, if not disposed of properly, causes serious environmental impacts.

One of the ways to mitigate the impacts on the environment is the use of residues in agriculture, such as fertilizers and poultry litter is one of the residues with potential for use for this purpose.

At the same time, it is important to infer that the acquisition of chemical fertilizers has been suffering increases in acquisition values, impacting exorbitant increases in fixed costs; something that undermines the sustainability and economic efficiency of agricultural production (ALLAM et al., 2022). Thus, one strategy to reduce production costs and make agricultural production sustainable is the use of organic fertilizers.

The avian compost has satisfactory results when compared to other compounds, as they influence the physical, chemical and microbiological characteristics. In addition to increasing base saturation and raising levels of nutrients such as calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P) and zinc (Zn) (SCHALLEMBERGER et al., 2019). According to Santos and Camargo (2008), organic sources can replace all or part of the P required by plants.

With the combination of minerals with organic fertilizer, such as poultry litter, organominerals originate. This tool meets the current need for sustainability reconciled with socioeconomic development.

The enrichment of organic fertilisers, mainly such as P, allows them to be used mainly in the basic fertilisation of both annual crops and perennial pastures.

It is worth mentioning that P is one of the nutrients responsible for the development of the root system at the beginning of the development of the plant organism, responsible for the increase in vigor, better use of water, resistance to pathogens and among others (MALAVOLTA, 2006).

2 DEVELOPMENT

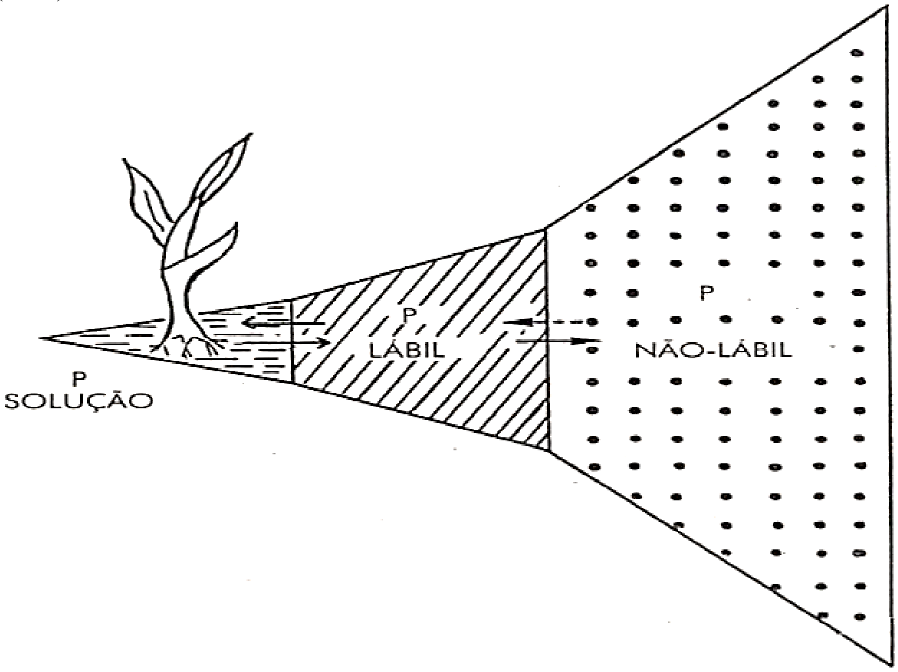
2.1 P DEFICIENCY IN CERRADO OXISOLS

The soils of the Cerrado, for the most part, are formed by Oxisols, characterized by being highly weathered, porous, deep and deficient in some essential minerals for crops of agronomic interest. However, they have a great capacity for technified agriculture and livestock, due to the favorable climate for crop development. It has privileged relevance for the expansion of agriculture specialized in grains, due to the ease they offer to the traffic of agricultural machinery (MAROUELLI, 2003).

The limiting factors for agricultural use in these soils are the deficiency of P, Ca, nitrogen (N) and high content of aluminum (Al), a toxic element for most commercial crops, since it becomes necessary to apply correctives and fertilization, establishing means that make it possible to synchronize the release of nutrients with the time of greatest demand for the crops. thus avoiding their immobilization or accelerated mineralization (SANZONOWICZ, 2010; PITTA et al., 2012; BOTTEGA et al., 2013).

The amount of total P in Oxisols is relatively high, however, it is not found in its labile form, i.e., accessible to plants in the soil (SANTOS, 2009), as can be seen in Figure 1.

Figure 1. Diagram showing the relationship between non-labile phosphorus fractions and phosphorus in soil solution. Adapted from Raij (1991).



P is an essential macronutrient, effectively participates in several metabolic processes in the organism of plants, has a lot of influence with other soil nutrients, such as Al, iron (Fe) and Ca. It is also present in organic forms and its low rate of propagation in the soil makes it less available for soil/plant (ALMEIDA et al., 2016).

Thus, the application of high doses of P is essential, as it is essential for the success of crops, whether grain or forage. P is one of the most important nutrients and deserves greater concern during management, due to its enormous adsorption capacity in the mineral phase of the soil (SCHONINGER et al., 2013).

Paiva et al. (2012) observed that N and P doses increased their availability in the soil, positively influencing the weight of green corn ears. The crop has an excellent response to phosphate fertilization more than to nitrogen fertilization, demonstrating that in Cerrado soils, P is more limiting to corn production than N.

In the no-tillage system, the maximum use of P by the plants prevails, a factor attributed to the reduction of contact between the fertilizer and soil particles, resulting from the absence of turning and the presence of vegetation cover or straw on the soil surface, providing moisture retention (ROSIM et al., 2012).

Nunes et al. (2011) found that soybean yield in the 14th year of cultivation in the area was not affected by the source of phosphate fertilizer or by the mode of application, but by the cultivation system. The highest yield was obtained in the no-tillage system, due to higher P availability when compared to the conventional system.

The increase in the organic matter (OM) content, which occurs in a no-tillage system, increases the availability of P in the soil, which is mainly due to the competition of organic anions and functional groups of humic substances by the adsorption sites, which increases the concentration of the element in the soil solution

The positive effect of phosphate fertilization on forages has also been proven by Oliveira et al. (2012), with an increase in the number of tillers and dry mass of shoots and roots of Mombasa grass; by Almeida et al. (2013), also with Mpmbaça grass, which found an increase in the production of green and dry matter in the aerial part and also in the number of forage tillers; By Carneiro et al. (2017), who obtained positive effects on height and average number of tillers.

2.2 USE OF ORGANIC WASTE IN AGRICULTURE

Animal production chains generate a high amount of organic waste with a high degree of polluting agents and the irrational disposal of these in the environment causes serious ecological imbalances, however it can be minimized through environmental liabilities, such as its use in agriculture. When effluents are properly treated, they become interesting due to the enormous supply of excreted nutrients that were not used in the diet, these with high levels of N, P and K. Not to mention the enormous amount of organic material (KARUNANITHI et al., 2015).

Organic fertilizers from animals fed a diet richer in concentrate tend to have a faster availability of nutrients than those animals fed with a diet richer in roughage, thus creating a very broad spectrum in relation to the release time of these nutrients, this is all related to the carbon/nitrogen ratio (C/N) present in the organic compost (SOCIEDADE BRASILEIRA DE CIÊNCIA DO SOLO, 2016).

The use of organic fertilizer provides significant changes in soil characteristics, providing greater porosity, increased water retention, greater formation of soil aggregates, and increased CEC. For this, it is necessary to transform this material into humus, or mineralization, through composting, which promotes a reduction in the C/N ratio of the organic compost (BATISTA et al., 2018)

In order to make the nutrients present in the organic fertilizer available to the plants, it is necessary to transform the organic fraction to the inorganic fraction mediated by the microorganisms present in the soil, a process called mineralization, which varies according to the composition of the organic fertilizer, the activity of the biota, soil characteristics and edaphoclimatic conditions (VANEGA CHACÓN et al., 2011).

2.3 POULTRY BEDDING

The poultry litter integrates part of the waste from the production system. In the house, it has the purpose of preventing the friction of the bird with the surface, absorbing moisture, incorporating feces, feathers, skin peeling and food remains. It is usually composed of wood shavings, rice husks or straw (VIEIRA, 2011).

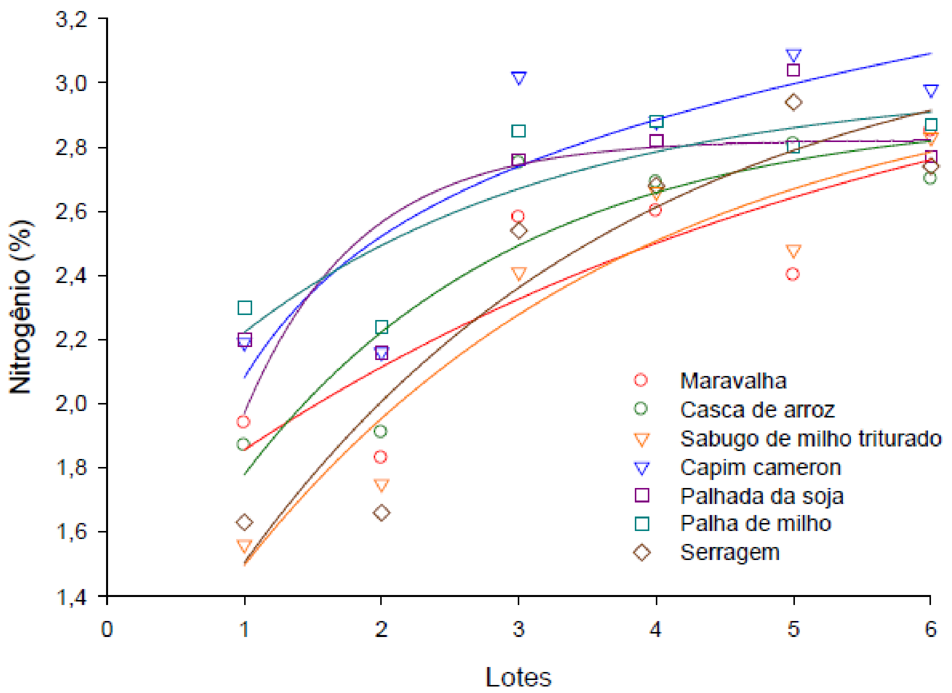
In order to be able to reuse the litter, it is necessary that it is handled and treated correctly, in order to mitigate the population of microorganisms that may harm the following batches. There are several types of management aimed at the inactivation and control of pathogens between batches. In the country, the most commonly used are windrow fermentation, the addition of lime to the litter and flat fermentation, which is summarized in the covering of the litter with canvas along the entire length of the aviary (MACKLIN et al., 2006).

It is important to highlight that when the occurrence of severe sanitary cases is observed, all material must be removed for incineration and cleaning of the shed, followed by a sanitary vacuum before the accommodation of the next batch (SILVA, 2012).

Reuse can be done for up to 12 batches, however, it is mostly used for six batches in a row. At the end of each batch, the crusts and pasted materials are removed, and if the remaining litter is not very thick, a new substrate is incorporated (MENDES et al., 2004).

Both the materials used as bedding and the number of passes influence the availability of nutrients. Avila (2007) found that with the increase in the number of passes, the N content increased and Cameron grass, crushed corn cob, soybean straw and sawdust provided greater availability (Figure 2). These results emphasize the need to understand the composition of poultry litter before recommending doses for application in the field.

Figure 2. Nitrogen (N) contents in various poultry litters varying according to the raw material used in relation to the number of flocks of birds.



Fonte: Adapted from Avila (2007).

Table 1 shows that with the increase in the number of broiler passes (3-4 to 7-8 batches), there is an increase in nutrients. From the data presented, the increase was 16% of N, 12% of P2O5, 28% of K2O, 11% of Ca and 20% of Mg. The type of bird also influences the concentration of nutrients.

Table 1. Average values of nutrients and dry matter content in different amounts of chicken litter reuse and different categories.

Organic material	C-org.	N2	P2O5	K2O	Ca	Mg	Dry Matter
	- % (m/m) -						
Frango Bed (3-4 lots)	30	3,2	3,5	2,5	4,0	0,8	75
Frango Bed (5-6 lots)	28	3,5	3,8	3,0	4,2	0,9	75
Frango Bed (7-8 lots)	25	3,8	4,0	3,5	4,5	1,0	75
Peru Bed (2 lots)	23	5,0	4,0	4,0	3,7	0,8	75
Layer bed	30	1,6	4,9	1,9	14,4	0,9	72

Source: Adapted from BRAZILIAN SOCIETY OF SOIL SCIENCE (2016).

Chicken litter was widely used in cattle feed in Brazil. After several outbreaks in other countries by Bovine Spongiform Encephalopathy, commonly known as "Mad Cow Disease", in 2001, the Ministry of Agriculture, Livestock and Supply (MAPA) prohibited its use throughout the country through Normative Instruction (IN) No. 15, in its 2nd article (BRASIL, 2009).

Normative Instruction No. 15 was annulled by IN No. 7 of March 2004, declaring exclusively the importation of products that could cause Bovine Spongiform Encephalopathy and did not refer to any residue of national origin. However, in the same month of 2004, IN No. 8 came into force, condemning throughout the national territory the production, commercialization and use of products intended for the feeding of ruminants that contain proteins and fats of animal origin, including poultry litter (JÚNIOR, 2010).

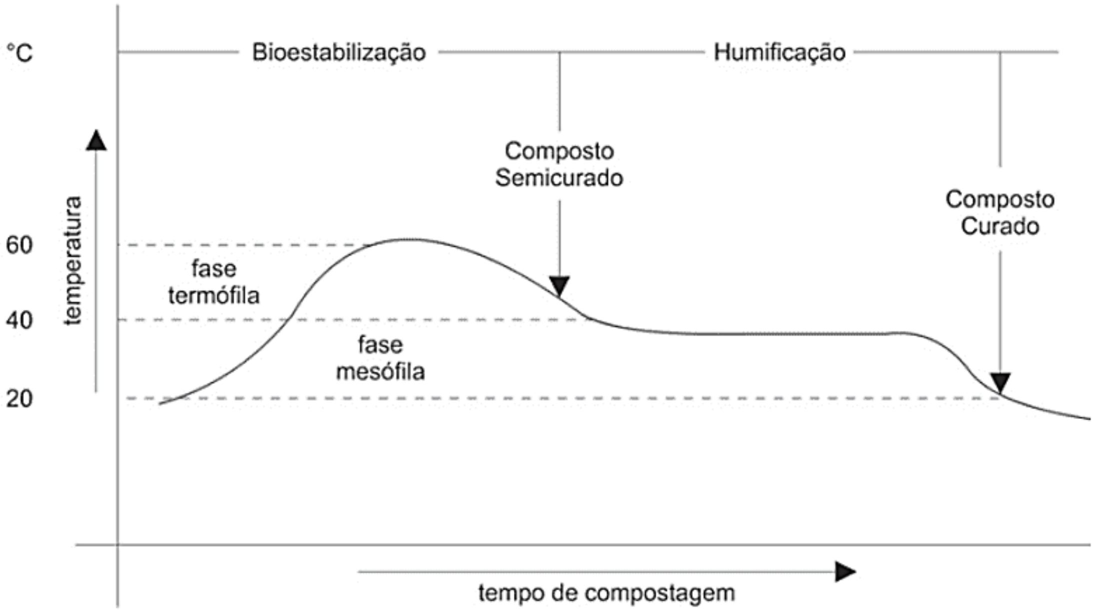
2.4 POULTRY LITTER TREATMENT THROUGH COMPOSTING

Composting is a set of techniques characterized by the biological process of decomposition, where microorganisms convert organic matter into carbon dioxide, biomass, heat, and humic substances. After the composting process, the final product tends to improve the physical, chemical and biological properties of the soil, without causing environmental problems. Composting enables an effective disposal of organic waste, preventing its agglomeration in landfills or in the environment (HAO, 2016).

The composting process can be summarized in phases (SILVA, 2010; KIMURA, 2014) (Figure 3).

- **Mesophilic phase:** defined by the increase in temperature up to 40°C as a result of the exponential development of microorganisms and degradation of easily degradable compounds, such as sugars and proteins.
- **Thermophilic Phase:** thermophilic microorganisms replace mesophilic microorganisms, the temperature exceeds 40° C, increasing the rate of biodegradation of lipids, hemicellulose, cellulose and lignin, reducing the mass and volume of the rakes.
- **Cooling phase:** decrease in microbial activities, thermophilic populations are replaced by mesophiles, due to the decline in temperature.
- **Maturation phase:** this is the last stage of the transformation of complex molecules into humic substances.

Figure 3. Summary of the phases of the composting process, highlighting the interaction between temperature and time.



Source: D´ALMEIDA; VILHENA, 2000.

To differentiate the temperature phases, simply introduce rebar to the bottom of the windrows, until the end of the composting process. These iron bars should be removed to check the temperature every two or three days until the first turn, and once a week, until the end of the process.

The main factors that interfere with composting are microorganisms, aeration, humidity, temperature, C/N ratio, chemical and physical characteristics of the materials involved, pile dimensions and the stability of the biodegradability of the microbial population, these when misconducted, can lead to low composting efficiency resulting in a compost of inferior quality (XI et al., 2015).

Table 2 shows the appropriate and desirable amplitude of each of these items, in order to have an efficient composting process.

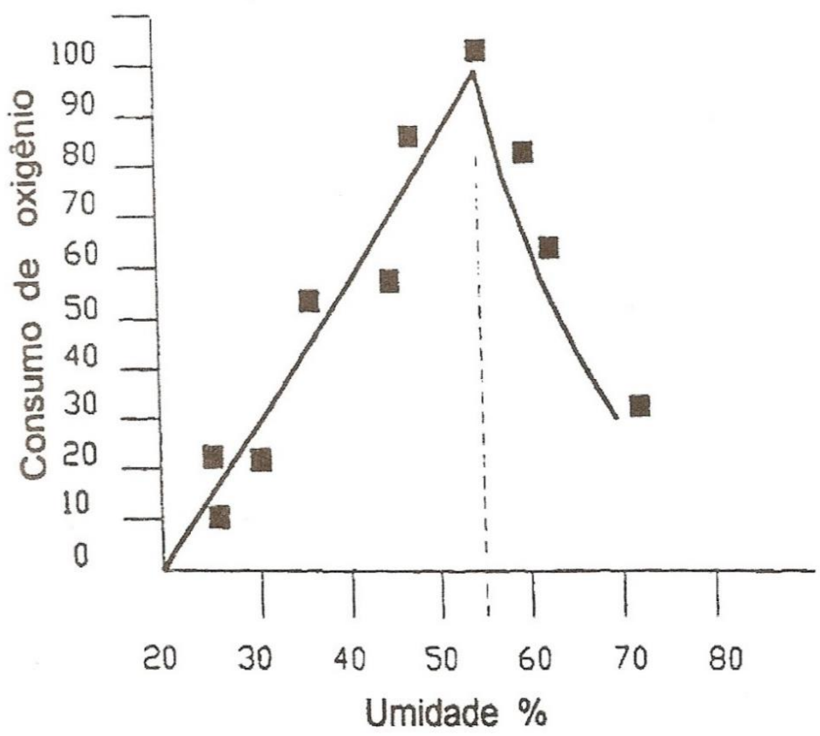
Table 2. Recommendations for efficient composting.

Conditions	Adequate amplitude	Desirable breadth
Oxygen Concentration	Greater than 5%	Much higher than 5%
Moisture	40 – 65%	50 – 60%
Temperature (ºC)	43,5 – 65,5	54,5 – 60,0
Carbon:Nitrogen Ratio	20:1 – 40:1	25:1 – 30:1
Moisture	40 – 65%	50 – 60%
ph	5,5 – 9,0	6,5 – 8,0

Source: Adapted from Soares e Silva (2021).

High levels of humidity leave the material soaked, impairing the aerobic decomposition of the material, due to the lack of oxygen, generating bad odors. Oxygen consumption, which is the digestion of organic matter, increases considerably with the increase in moisture content from 25% to 55%, falling almost vertically when it exceeds this last value (Figure 4).

Figure 4. Effect of humidity on oxygen consumption in household solid waste composting.



Fonte: GOLUEKE (1975).

In order to achieve the desired values of the C/N ratio, it is often necessary to mix materials according to the different compositions of the residues (Table 3).

Table 3. C/N ratio of some wastes.

Material	C/N Ratio
Bovine manure	18:1
Bird Manure	10:1
Pig manure	19:1
Sheep manure	15:1
Equine manure	18:1
Aviary bedding	14:1
Rice: husk and straw	39:1

Fonte: Adapted from Kiehl (1998).

Composting has numerous advantages, as it enables the decomposition of carcasses remaining in poultry litter, thus an excellent technique for treating solid waste (CESTONARO et al., 2010; ORRICO JUNIOR et al., 2012; PAIVA et al., 2012).

Orrico Júnior et al. (2010), in the study evaluating the effectiveness of the composting process in the treatment of poultry litter waste and poultry carcasses, observed that the percentage of bones in relation to the initial amount of carcasses, which resisted the composting process, was 2.95%, most of them with rustic structures.

Composting programs are in focus, especially in the treatment of poultry waste such as chicken litter and layer waste. Due to environmental pollution and the requirements of MAPA (Annex IV, IN n°25/2009), for biosafety reasons, waste of animal origin must be treated (BRASIL, 2009).

Properly conducted composting is able to mitigate most of the pathogenic microorganisms present in the organic matter, thus reducing the risk of contamination. The mechanisms of pathogen elimination are understood by the combination of temperature, competition between microorganisms and exposure time. Among the parameters that are easy to monitor is temperature (LONGHURST et al., 2010).

However, during the composting process, a considerable amount of N is lost by volatilization in the form of ammonia (NH3). Studies indicate that the most significant losses occur during the initial stages of composting, when there is a greater amount of easily decomposed organic material and a rapid increase in temperature due to the activity of microorganisms (JANCZAK et al., 2017).

The high temperature during the composting process is the result of the biodegradation of organic matter by microorganisms, which can become a threat to the process if the temperature exceeds 75°C, leading to a reduction or even a halt in microbial activity (MASSUKADO, 2008). Studies show that the temperature should be maintained up to 60°C, being able to efficiently reconcile the mitigation of pathogens and high levels of biodegradation (FIALHO, 2007).

It was observed in a study conducted by Ferreira (2021) that composting was effective in significantly reducing the population of thermotolerant coliforms in poultry litter waste, both organic and conventional. In addition, composting was effective in eliminating viable helminth eggs in all animal waste tested, reinforcing its efficiency as a method of organic waste treatment.

2.5 USE OF POULTRY LITTER AS ORGANIC FERTILISER

Due to the high percentage of organic matter contained in poultry litter, this is considered an interesting residue from an agronomic point of view, for commercial crops. However, this use must have a technical basis and be consistent with the reality of each producer, knowledge of the needs of the soil, plants and especially the chemical composition of these compounds.

Noce et al. (2014) using poultry litter as fertilizer found that it provided positive effects on corn yield for silage and, depending on the market climate and regional availability of the product, there is the possibility of replacing chemical fertilization.

The use of poultry litter as an organic fertilizer for pasture during the off-season period on the corn crop demonstrates viability, as it allows gains in crop productivity due to its high level of nutrients (NOVAKOWISKI et al., 2013).

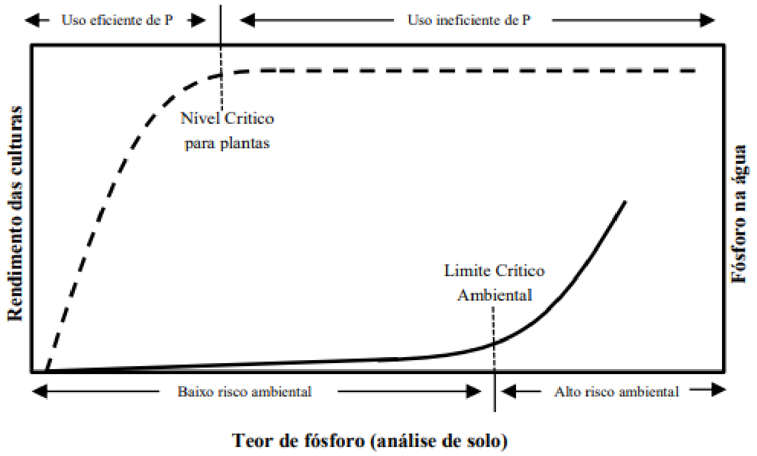
Portugal et al. (2009) observed the effects of the use of different doses of chicken litter for two consecutive years on soil chemical changes and dry matter accumulation of *Urochloa brizantha* cv. Marandu. The use of this residue significantly increased the dry matter production (8 t $^{ha-1}$) when compared to the treatment that did not receive the residue (4 t $^{ha-1}$).

Silva et al. (2013) using only laying hen manure, found an increase in the production of green mass and in the length of *Urochloa grass. brizantha* cv. Thus, the level of soil organic matter is highly correlated with the production potential of pastoral systems, especially in systems where fertilization is not used. The recovery and effective maintenance of adequate OM levels are essential for the sustainable development of livestock in tropical regions.

For the use of poultry litter as fertilizer in pastures, it is absolutely necessary to verify and analyze its source material, it is essential to have easy biodegradation and to be free of pathogenic microorganisms that may contaminate the soil and the water table (BENITES, 2011).

The systematic application of chicken litter in the soil can cause accumulation of P. This accumulation occurs due to the concentration of N, P2O5 and K2O which is practically 1:1:1 (Table 1), while for most crops the requirements of N, P2O5 and K2O are 6:1:4; 6:1:3 respectively. One of the precautions when recommending the appropriate dose is to use the critical nutrient for the calculation basis. In addition to the agronomic response, which is the effect on crop yields, it is necessary to observe the environmental response

Figure 5. Schematic representation of the relative yield of crops and the amount of P in the water as a function of the available P content in the soil, highlighting the critical level of P for the crops and the critical environmental limit.



Cast iron: Gatiboni et al. (2014).

2.6 ORGANO-MINERAL FERTILIZERS AND THEIR USE

When organic fertilizers are complemented with mineral fertilizers, they give rise to organo-mineral fertilizers (SOUSA, 2012). Solid organo-mineral fertilizers must contain at least 8% organic carbon, 10% primary macronutrients N, P and K alone (BRASIL, 2009).

According to NORMATIVE INSTRUCTION No. 23, OF AUGUST 13, 2005, of the Brazilian Legislation, organomineral fertilizer is defined as a product resulting from the physical mixture or combination of mineral or organic fertilizers, which can be in crumbled, granulated or pelleted form (ALANE, 2015).

Organic compounds, together with mineral sources, are a tool that intensifies the efficiency of mineral fertilizers, minimizing crop fertilization costs and providing improvements in soil characteristics, through a greater supply of nutrients, which causes greater activity of microorganisms present in the soil, increasing the stability and sustainability of the system (RABELO, 2015; ULSENHEIMER et al., 2012).

Organo-mineral fertilizers have great potential for agricultural application in annual and perennial crops. This encompasses valuable commodities such as corn, soybeans, beans, wheat, cotton, as well as perennial pastures. From a sustainable production perspective, its use is economically viable, reducing dependence on mineral fertilizers and contributing to environmental conservation (MALAQUIAS; SANTOS, 2017).

According to Andrade et al. (2012), organo-mineral fertilizers are superior to chemical and organic fertilizers, because the absence of some essential nutrients for plants through the combination of fertilizers can be easily supplied, and the absence of one nutrient can be found in greater quantities in the other.

Tiritam and Santos (2012), studying the influence of fertilization with organomineral fertilizer, observed satisfactory results for off-season corn, as the treatment that used organomineral fertilizers was superior in relation to the others that did not use fertilizer, with higher productivity in corn production and improvements in soil properties.

According to Borges et al. (2015), the use of organomineral fertilizer in soybean planting provided superior productivity when compared to mineral fertilization treatments, and may be a viable possibility from an agronomic and economic point of view in crop management.

Silva et al. (2015) found that organomineral fertilizers increase the levels of nutrients such as Ca and Mg from 6.8 and 3.3 cmolc $^{dm-3}$ to 8.2 and 4.6 cmolc dm-3 in the soil layers that were studied and reduced aluminum saturation from the lowest dose (60 kg $^{ha-1}$ of N; 90 kg $^{ha-1}$ of P2O5 and 100 kg $^{ha-1}$ of K2O).

3 CONSIDERATIONS

1 DUE TO THE FACT THAT IT IS A GOOD SOURCE OF NUTRIENTS AND ORGANIC MATTER, CHICKEN LITTER HAS THE POTENTIAL TO BE USED IN AGRICULTURE. HOWEVER, IT IS NECESSARY FOR THIS WASTE TO GO THROUGH A COMPOSTING PROCESS, WHICH IMPROVES ITS AGRONOMIC CHARACTERISTICS, IN ADDITION TO ELIMINATING PATHOGENIC MICROORGANISMS WHEN THE TEMPERATURE OF THE COMPOST PILES IS CONTROLLED. THERE IS STILL THE POSSIBILITY OF ENRICHING THIS MATERIAL WITH CHEMICAL FERTILIZERS, GIVING RISE TO ORGANOMINERALS.

Both composted poultry litter and organominerals, if used rationally, have great potential to be used in agriculture, promoting soil improvements and reducing production costs.

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