POULTRY LITTER AS FERTILIZER FOR SOYBEAN

The poultry industry is the largest income-producing agricultural commodity in Mississippi, with a farm gate value of $3.84 billion in 2024. Broiler production value was $3.34 billion, which amounted to 87.3% of the Mississippi poultry industry's income. Egg production value was $484 million, which accounted for most of the remainder of the income from poultry enterprises [MSU-DAFVM 2024].

There are 3200+ poultry farms in Mississippi [MSU-DAFVM 2024]. It is estimated that a single poultry house on one of these farms annually provides about 200 tons of litter [PL]. Therefore, there is an abundance of poultry litter [the bedding material and contained poultry manure] that is available for use as fertilizer.

A 2005 article presents the findings from a study conducted at Mississippi State University on a silty clay loam soil where using PL as a fertilizer for soybeans was compared to using commercial fertilizer. The findings and conclusions from that study are:

- Using PL litter vs. commercial fertilizer increased soybean yields by 3.3 bu/acre [9%].
- The potential for soybean to remove soil N and increase yield from PL application should encourage soybean as an alternative crop for PL fertilization.

A 2011 article presents findings from a 10-year Alabama research project that investigated the use and effects of PL on soybean and corn yields when both crops were grown on a fine sandy loam soil in the northeast part of the state.

- Results from the study showed that PL application resulted in average 10.8 [9.5%] and 4.1 [11.7%] bu/acre increases in corn and soybean yields, respectively.

Research in Arkansas showed that PL is a legitimate phosphorus [P] and potassium [K] alternative to commercial fertilizer for soybeans that are grown on soils that require P and K fertilization to realize maximum yield potential.

A decade-long [2005-2015] study conducted near Bowling Green Kentucky [37° N latitude] compared using PL to supply all nutrients [FBL] to a corn crop vs. using half PL [HPL] plus half chemical fertilizer [CF] and full CF in both conventional tillage [CT] and no-till [NT] systems. The results from this study indicated that: 1) both FPL and HPL resulted in a higher cation exchange capacity [CEC] and more total soil carbon [C], total soil N, and organic matter [OM] than CF at the end of the 10-year period; 2) FPL resulted in much greater soil P, iron, copper, and zinc than HPL and CF; 3) FPL, HPL, and CF produced similar average corn yields across the 10-year period; and 4) tillage had no significant influence on soil nutrient levels or soil chemical properties. These results led the authors to conclude that HPL plus half CF is a better use option for PL in corn production than is using the FPL.

A wheat-soybean doublecrop study conducted in Alabama on loamy sand and sandy loam soils in 2014-2016 evaluated no fertilizer N vs. 120 lb. N/acre applied to the wheat crop. Nitrogen was provided by either inorganic N fertilizer, PL, or a combination of the two in varying amounts to equal the 120 lb. N/acre rate. Combinations of PL + inorganic N fertilizer to equal 120 lb. N/acre applied to the wheat crop produced equivalent wheat yields that exceeded those from both the no fertilizer N treatment and the treatment that received N fertilizer totally from PL. None of the treatments affected yield of soybeans following the wheat crop. These results indicate that wheat in a wheat-soybean doublecrop production system can receive its required N fertilizer from a combination of inorganic N fertilizer and PL, but should not from PL alone.

Results from the above studies lead to the same conclusion—i.e. PL is an effective fertilizer and using it in combination with inorganic fertilizers is a beneficial agronomic practice.

The majority of Mississippi's poultry houses are located in the southeastern region of the state [MSU-DAFVM 2024], whereas the state's major crops are produced in the Delta and northeastern counties. Thus, the cost of purchasing, hauling, and spreading PL on Mississippi crop fields that are not close to the litter source should be determined for each intended site of application before it can be practically considered as an economical fertilizer.

The estimated costs in **Table 1** can be used to determine the total cost associated with using PL as a fertilizer. These costs are based on the following stipulations.

- 2-year-old fresh PL [not stockpiled]–primarily wood shavings, with some sawdust or rice hulls;
- 25 tons per load that is delivered to the application site;
- $0.16/mile/ton hauling costs–80 or more miles (check with vendor for short-haul rates); and
- 2 tons/acre spread on producer field.

Individual lots of PL vary in their N-P-K contents. The sources in **Table 2** can be used as a guide to determine how much fertility to expect in each ton of PL.

The values in **Table 2** show the importance of vendors furnishing a nutrient analysis of the product they are delivering so the recipient knows the exact amount of nutrients that is being received. The basic tenets of PL sampling for nutrient analysis are given in MSU-ES Pub. 2878. The Miss. State Chemical Laboratory or a commercial laboratory can analyze PL samples.

Table 1. Costs of poultry litter [PL] handling.

Item/Activity	Cost
Removal of litter from poultry house	$8/ton
Loading on truck	$10/ton
Hauling to producer field	<80 miles--$0.20/ton/mile ≥80 miles--$0.16/ton/mile
Spreading on producer field	$10/ton

Hauling 25 tons 100 miles and spreading 2 tons/acre on a site results in:

$8 + $10 + $10 = $28/ton x 2 tons/acre = **$56/acre for material loading and spreading**;

$0.16/mile/ton x 100 miles = $16/ton x 2 tons/acre = **$32/acre for hauling**.

$56 + $32 = $88 total cost per acre for 2 tons/acre spread on site 100 miles from litter source.

Table 2. Typical nutrient content of fresh PL on an "as is" basis [no adjustment for moisture] from linked sources.

Source	N-P_2O_5-K_2O analysis [N-P-K]; lb./ton
Oklahoma State Univ.	63-61-50 [63-27-42]
Miss. State Univ. Pub. 2878	47-69-61 [47-30-50]
Clemson Univ.	72-69-46 [72-36-38]
Univ. of Georgia	64-54-48 [64-24-40]
Private Lab. Sample	69-76-57 [69-33-47]
Alabama Coop. Ext. Serv.	62-55-41 [62-24-34]; n=207
Univ. of Arkansas	62-69-60 [62-30-50]; n=297
Univ. of Arkansas	55-60-63 [55-26-52]; n=100
Tewolde et al.	[65-23-52]

PL may contain significant amounts of Calcium, Magnesium, Sodium, and Sulfur, and minute amounts of micronutrients. Thus, some value can be attributed to these elements. Also, there is the intangible value of adding this amount of OM to the soil.

The figures and data in the two tables can be used to estimate the feasibility of and value from applying PL in lieu of commercial fertilizer to crop production fields in Mississippi that are some distance from the site of the PL source.

Proper Application Time and Storage

Numerous sources indicate that spring is the ideal time to apply PL so that its maximum nutrient-supplying potential is realized, especially in the Midsouth which has warm fall and winter months. This is supported by results from 3 years of research conducted by Tewolde et al. in Mississippi. Their results are summarized below.

- Row crop producers may find that spring application of PL interferes with other more critical operations, and thus choose to apply PL in the fall.
- Often, PL availability and pricing may be more favorable in the fall than in the spring. This can entice row crop producers to acquire and apply PL in the fall or winter months.
- In the Midsouth [site of this research], PL applied in the fall lost up to 15% of its fertilizer potency.
- Applying PL in the fall resulted in about a 15% reduction in corn growth and grain yield vs. applying the same amount of PL in the spring.

So what is to be done with PL that is available but will not be applied until the spring? Ritz et al. in Univ of Georgia Ext. Bull. 1230 provide the background and guidelines for proper temporary storage of PL until the disired time of application to cropland.

- The maximum value of PL as a fertilizer occurs at the time it is removed from a poultry house. Storing PL properly will assure the most beneficial use of its contained nutrients and prevent water contamination.
- Stockpiles of PL should be placed on a high, well-drained location away from drainage ditches and covered with anchored plastic sheeting [6 mil thick) to protect the PL from rain and runoff.
- Use berms or diversion ditches to prevent water from running into or through the stockpile.
- Use a ground liner (6 mil plastic) to prevent leaching of PL contents into the groundwater if/when the pile is exposed to rain.
- For large poultry operations, permanent structures may be the most practical and economical for storing PL. In tall structures, sidewall panels may be necessary to protect the PL from blowing rain.
- Operate PL storage facilities in a manner that will prevent fires resulting from overheating of litter. This includes: 1) stored PL should not exceed 7 feet in depth; 2) litter of different ages should be stored separately; 3) prevent storm water intrusion; and 4) monitor the internal temperature of the litter pile—move litter that exceeds 180° F to prevent spontaneous combustion.
- Using PL storage facilities and structures is considered a Best Management Practice for protecting the surrounding environment and for maximizing fertilizer value of PL that will be applied to cropland.

JUNE 2021 UPDATE

Results from recent research projects conducted on a Blackland Prairie soil in northeast Mississippi provide information that can be used to refine how and when PL can be used as a fertilizer for Midsouth crops, especially soybeans. Summaries of those research projects follow.

An article by Feng et al. titled "Soil physical and hydrological properties as affected by a five-year history of poultry litter applied to a cotton-corn-soybean rotation system" reports results from a field study that was conducted on a Leeper fine sandy loam soil for 8 years in corn, cotton, and soybean rotations at Verona, Miss. Details of and results from that study follow.

- The nonirrigated field study was conducted to determine the potential influence of PL application on soil physical and hydrological properties.
- The study consisted of four crop rotations that involved continuous cotton and three rotations schemes with cotton, corn, and soybeans for 5 years [2010-2014]. All plots were planted with soybeans from 2015 through 2017.
- Fertility treatments consisted of 1) no fertilizer, 2) a standard fertilizer treatment with conventional synthetic fertilizers applied to meet the nutrient needs of each crop in the rotation, and 3)

uncomposted PL applied in an amount to meet the full N requirements of the cotton crop. No synthetic N fertilizer was applied to the cotton or soybean crops, but corn received synthetic N above that supplied by PL to meet its higher demand for N. P and K fertilizers were applied to soybeans based on soil test recommendations.

- The consequences of the 5 years of fertility treatments on soybeans were measured in the sixth [2015] and eighth [2017] years of the study. Soil properties measured in these years were bulk density [BD], penetration resistance [PR], saturated hydraulic conductivity, soil water content at field capacity [FC] and permanent wilting point [PWP], infiltration rate, and water stable aggregates.
- Yearly PL application in the 2010-2014 period reduced BD by 6% in 2015 and 4% in 2017 compared to that of soil that received synthetic fertilizers.
- PR did not differ between the PL and fertilized treatments in 2015 and 2017.
- PL addition in the 2010-2014 period resulted in a significant increase in FC and PWP water content of 20 and 41% in 2015 and 8 and 13% in 2017 compared to that following no added fertilizer and the addition of commercial inorganic fertilizer, respectively.
- Saturated hydraulic conductivity of soil amended with PL was about three times greater than that of soil amended with inorganic fertilizer.
- PL addition from 2010-2014 improved soil aggregate stability by 17 and 31% in 2015 compared to that of the other two fertility treatments, respectively. There were no differences in soil aggregate stability among treatments in 2017.
- Soybean yields from the plots that received PL vs. those that received inorganic fertilizer were a significant 8% more in 2015 [68.2 vs. 63.2 bu/acre] and 11% more in 2017 [67.9 vs. 61.3 bu/acre], thus suggesting that the improvement in soil properties following the addition of PL was associated with a soybean yield increase.
- Crop rotation did not significantly affect soil physical and hydrological properties.
- These results suggest that the addition of PL as a fertilizer is an effective management practice for improving soil health that will in turn contribute to increased soybean yield.
- *(Note: This research was financially supported by MSPB for a Project titled "Stabilizing dryland soybean yield and profit in dominant soils across Mississippi").*

An article by Tewolde et al. titled "Managing soil nutrient buildup by rotating crops and fertilizers following repeated poultry litter applications" reports results from a field study that was conducted on a Leeper fine sandy loam soil for 5 years (2010-2014) in cotton, corn, and soybean rotations at Verona, Miss. Details of and results from that study follow.

- The nonirrigated field study was conducted to determine whether or not buildup of nutrients resulting from repeated application of PL to the same site can be managed by rotating PL and synthetic N fertilizers and rotating cotton, corn, and soybean crops in the southeastern US.
- The study consisted of two factors–four levels of crop rotation involving cotton, corn, and soybeans, and five fertility strategies that were 1) an unfertilized control [UTC], 2) a standard fertilization with synthetic fertilizers applied to meet the requirements of each crop [STD], 3) a P-based PL fertilizer application every year for 5 years [PL5P], 4) an N-based PL application every 5 years PL5N], and 5) an N-based PL application in the first 2 years and synthetic N fertilizer applied at the same rate as in 2 above in the last 3 years of the study [PL2N]. Fertilizers applied in treatments 2 [STD], 4 [PL5N], and 5 [PL2N] above were based on the N requirement of cotton, while the fertilizer applied in treatment 3 [PL5P] above was applied in an amount to meet the expected P removal by cotton. When corn was planted in the rotation, synthetic N fertilizer was applied to supplement N supplied by PL in order to meet the higher N demand by corn. Applications of P and K fertilizers in treatment 2 [STD] above were made according to soil test recommendations for each crop grown in the rotation.
- Extractable nutrients were measured in soil samples taken after crop harvest each year. Both fertility and rotation treatments affected nutrient levels, but the fertility by rotation interaction was never significant.
- P is the element that most accumulates in the soil following repeated PL applications, and it was elevated more than three times that of the STD when PL was applied to meet cotton's N requirement [treatment 4–PL5N] in this study. When PL was applied as in treatment 3 above [PL5P], this excess accumulation of P did not

occur; however, synthetic N fertilizer had to be applied to meet the N requirement of the cotton and corn crops. Thus, the authors concluded that the P-based PL application [PL5P] is an effective method for managing PL application. However, this method will require the addition of synthetic N each year to cotton and corn crops.

- Results from this research showed that K depletion is a concern when fertilizing crops with PL, especially when soybeans are grown in a rotation scheme. Thus, extractable K in the soil should be monitored when PL is used as a fertilizer.
- Results from the study showed that magnesium buildup in the soil did not occur with the P-based application strategy. Extractable calcium was not affected by the fertility treatments.
- Extractable zinc and copper accumulated in the soil regardless of PL management strategy, but the authors did not attach concern to this since their documented toxicity is not widespread. Extractable iron also accumulated in the soil in response to the PL applications, but its magnitude was small and was not a concern. Extractable manganese was not affected by the PL treatments.
- In this study, crop rotation did not clearly and consistently affect residual soil nutrients.
- From these results, the authors concluded that 1) when excess nutrients accumulate in the soil as a result of repeated PL applications, rotating fertilizers where PL application is suspended for 2-3 years during which time only N fertilizer is added will return soil nutrient status to near initial levels and may be more efficient; 2) applying PL based on the P and/or N need of the crop will likely result in soil K depletion, which will be problematic when soybeans are grown in the rotation; and 3) crop rotation will aid in reducing P and K buildup in the soil, but may not be as effective as rotating PL with synthetic fertilizers to manage soil nutrient buildup that may result from repeated PL application.

The results from the above two studies show that 1) using PL as a fertilizer will improve soil health attributes, 2) PL should be rotated with synthetic fertilizers to ensure a stable soil nutrient status, and 3) PL application strategy should be managed to ensure that major nutrients P and K that are needed for crop development are at the proper level in the soil. This will require monitoring their soil levels when PL is applied as a fertilizer to ensure proper adjustment of fertilization strategy involving PL and inorganic fertilizers.

JULY 2021 UPDATE

A producer near Hollandale, Miss. called to update price information for applying poultry litter from South Miss. to his farm. His actual total cost that includes loading the truck and hauling 28 tons/load to the site of application [$40/ton x 2], and spreading 2 tons/acre to the application site [$14/ton x 2] is $108/acre.

JAN. 2022 UPDATE

An article by Tewolde et al. titled "Yield and nutrient removal of cotton-corn-soybean rotation systems fertilized with poultry litter" is a companion article to the preceding article that is summarized above. Details of and results from the study follow.

- The nonirrigated field study was conducted to determine the impact of PL and synthetic fertilizers applied to a cotton-corn-soybean rotation system as a way to prevent nutrient buildup from PL application to the soil.
- The study consisted of two factors–four levels of crop rotation involving cotton, corn, and soybeans, and five fertility strategies that were 1) an unfertilized control, 2) a standard fertilization with synthetic fertilizers applied to meet the requirements of each crop, 3) a P-based PL fertilizer application every year for 5 years, 4) an N)-based PL application every 5 years, and 5) an N-based PL application in the first 2 years and synthetic N fertilizer applied at the same rate as in 2 above in the last 3 years of the study. Fertilizers applied in treatments 2, 4, and 5 above were based on the N requirement of cotton, while the fertilizer applied in treatment 3 above was applied in an amount to meet the expected P removal by cotton. When corn was planted in the rotation, synthetic N fertilizer was applied to supplement N supplied by PL in order to meet the higher N demand by corn. Applications of P and K fertilizers in treatment 2 above were made according to soil test recommendations for each crop grown in the rotation.
- Extractable nutrients were measured in soil samples taken after crop harvest each year.
- Both fertility and rotation treatments affected nutrient levels, but the fertility by rotation

interaction was never significant.

- Resulting yields of all three crops indicated that the soil used for the studies was responsive to fertilization.
- Results showed that PL application increased soybean yield in the same season it was applied, but the soybean yield increases were not profitable when related to the cost of the PL.
- Rotation did not affect yield of any of the three crops.
- Results showed that growing cotton does not deplete soil nutrients as much as growing soybean or corn. In fact, when averaged across years and fertility treatments, soybean removed more than 3-fold N and K than cotton, and more than 2-fold N and K than corn.
- Not surprisingly, nutrient removal among the fertility treatments was mostly dependent on the yield differences among the treatments.
- Results from this study identified a new strategy for applying PL as a fertilizer when cotton, corn, and soybean are grown in rotation. This new strategy involves applying PL at a relatively high rate for 2 years to meet the N need of cotton, followed by a cessation of PL application for the next 2 or 3 years during which only synthetic N fertilizer is applied to the cotton or corn crops. This strategy improved the economic yield of all three crops. This strategy also resulted in a reduced level of residual elements from repeated PL application.
- **The bottom line results are "The best strategy of managing PL application where cotton, corn, and soybean are grown in rotation is to fertilize cotton or corn with PL to supply 100% of cotton's N need, followed by growing soybean without applying any fertilization in the subsequent 2 or 3 years."**

FEB. 2022 UPDATE

A summary article from the Univ. of Arkansas about using PL as a fertilizer is presented in the article titled "Using chicken litter as part of a fertility program" by Espinoza and Fryer. Pertinent points from that article follow.

- The high price of commercial fertilizers will likely result in an increase in the use of PL as a fertilizer source for crops.
- The most important recommendation when using PL as a fertilizer is to obtain both a nutrient and moisture analysis of the litter close to the time of its application.
- Moisture content of litter can vary significantly, and this will determine its "as-is" nutrient content—i.e. nutrient content will be more concentrated in drier litter, or nutrient content reported on a dry basis should be higher than if reported on an "as-is" basis.
- Instructions for sampling PL to obtain a representative sample can be found in the Univ. of Arkansas factsheet titled "Sampling poultry litter for nutrient content".
- N in PL is mostly in the organic form that needs to be mineralized to a form that plants can use. For practical purposes, assume that 50-60% of the N in the litter will become available during the year of its application to cropland.
- Mineralization rate of N will be affected by both soil temperature and texture.
- When both soil temperature and moisture are near optimum levels, a large portion of the N in the litter is mineralized in 4-6 weeks.
- Using an average value for K_2O content of applied PL will likely result in either an over- or under-estimation of the actual amount of K fertilizer applied.
- All of the K in PL is in an inorganic form that is readily available to plants.
- It is estimated that 2/3 of the P in PL litter is in the inorganic form that plant roots take up.
- For fertility purposes, assume that at least 90% of both the P and K in applied PL will become available to plants in the year PL is applied.
- The Univ. of Arkansas recommends that PL be applied based on the P requirements of the crop to be grown on the site.
- The majority of PL is organic C; thus, it should provide many of the benefits that are derived from

soil organic matter.

- When applying PL as a fertilizer, it is important to ensure that the application is uniform across the swath width of the applicator.

MAY 2023 UPDATE

In an article titled "Liquid-state litter digester prototype makes struvite, biogas and clean water", author John Lovett of the Univ. of Arkansas System Division of Agriculture presents information about a system that turns poultry litter into struvite [$MgNH_4PO_4{\cdot}6H20$–magnesium ammonium phosphate], captures the bio-gas methane, and recycles most of the water it uses in the process. Click here for a summary of the results from Arkansas research with struvite used as a fertilizer on Midsouth crops.

The above process uses anaerobic digestion to 1) produce a stable fertilizer product that maintains the fertilizer value of the litter, 2) remove noxious odors associated with the litter, and 3) produce the renewable fuel methane. Also, the process would significantly reduce the content of pathogens that are associated with raw litter. The goals, methods, and anticipated outcome from this work can be found here.

As the title of the article states, the litter digester is a prototype–i.e. it is neither available nor proven for use on a large scale. However, the successful large-scale development and subsequent use of such a system would have a long-term impact on the entire U.S. poultry industry by significantly reducing the problems associated with disposal of PL. The process could also satisfy some portion of a poultry farmer's energy needs by capturing and using the methane that is a by-product of the anaerobic digestion.

MAR. 2024 UPDATE

A Feb. 2024 article titled "Straight scoop on poultry litter fertilizer" by Jennifer Latzke presents the following up-to-date information associated with use of PL as fertilizer. 1) In the first year following PL application to a crop field, the estimated value of the N, P, and K nutrients contained in the PL is about $40.76/ton. In subsequent years following PL application, the value of N and P combined drops to about $26.73/ton. 2) The author of this article iterates the value of testing all PL lots that are used as fertilizer to ensure the nutrient content. 3) In order for PL fertilizer to increase soybean yield, its application must be timed to about 2-3 weeks before planting. Thus, it should be applied in early spring vs. in the fall. 4) The distance from the PL source to its site of application will likely cause some farmers to consider facilities that can be used to store the PL prior to its application. Consult the information in the aforementioned publication by Ritz et al. in Univ of Georgia Ext. Bull. 1230 for valuable information about proper storage of PL for future use.

AUG. 2024 UPDATE

An article titled "MU study looks at poultry litter's impact on soybean yields" by Julie Harker provides results from a 6-year study that was conducted in northwest Missouri. Pertinent points and results from the study follow.

- The objective of the research was to determine how the addition of PL would affect soybean yield over time.
- 10 tons of PL were applied in 2018. The PL contained 60 lb. of N, 50 lb. of phosphate, and 27 lb. of potash per ton.
- Over the 6-year period of the study, average soybean yield was increased by 6.4 bu/acre, or 13%. This increase was not statistically significant and may not have been economical.
- These results showed that the addition of PL to a soybean production field is a management practice that will benefit soybeans. However, an economic analysis that includes the worth of the nutrients contained in the litter is necessary to determine if addition of PL to a field cropped to soybeans is in fact economically feasible.

DEC. 2024 UPDATE

According to NASS, in 2023 the states of Arkansas, Mississippi, and Tennessee together had about 20.5% of the U.S. production of broilers, and about 35.5% of broiler production in the southeastern U.S. This large-scale poultry production in these Midsouth states subsequently results in large amounts of PL that must be disposed of. This has largely been done by applying PL as fertilizer to fields used for crop production since it contains several of the plant nutrients used by commonly grown crops in the region.

In Ark. and Miss., the major portion of each state's poultry production is in areas that are not close to areas of large-scale crop production. Thus, PL that is generated exceeds the capacity of nearby land to absorb it. The cost of transporting the PL to areas where crops are produced in each state is often uneconomical, especially when fuel prices are high. Thus, research to determine new technologies that can be used to convert the PL to a useable product with significantly less volume that can be economically transported to sites of application is of paramount importance. That is why research that can significantly condense the volume of PL that is to be transported offers opportunity for PL to be a more economical fertilizer source.

An article titled "4 takeaways when fertilizing with chicken litter" highlights PL use by West Tenn. farmer Matt Griggs. He provides the following four points that should be considered when using PL as a fertilizer. 1) Know what you are paying for/applying to a field since PL nutrient analysis can vary among sources and even loads. 2) Determine the value of PL to the site of its application vs. its cost. 3) Prepare to wait for the full effect from its application since some of its contained nutrients will take time to become available to a crop. Other things to prepare for are how weather patterns will affect N volatilization and spread pattern. 4) Be cognizant of PL stockpile location in relation to nonfarm neighbors, and the conditions of PL storage until it is used.

Composed by Larry G. Heatherly, Updated Jan. 2025, larryh91746@gmail.com