



NUTRIENT RELEASE PATTERN AND MINERAL FERTILIZER EQUIVALENT OF DIFFERENT ORGANIC SOURCES

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(Date of Receiving-28-05-2025; Date of Acceptance-08-08-2025)

ABSTRACT

Organic amendments play a vital role in enhancing soil fertility by gradually releasing nutrients necessary for plant growth. This review synthesizes studies on the nutrient release patterns and mineral fertilizer equivalents (MFE) of different organic sources, including farmyard manure, poultry manure, biogas slurry, vermicompost, mushroom compost and biochar. Findings indicate that these organic materials have significant variability in the release rates of key nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and trace elements like zinc, copper, iron, manganese and boron. It is observed that poultry manure and biogas slurry have faster release rates of P, Ca, Mg and trace elements like Zn and Cu making them excellent alternative sources to chemical fertilizers for these nutrients. Biochar and FYM exhibited superior K release, while mushroom compost showed the highest manganese release. The mineral fertilizer equivalent (MFE) of these organic sources was determined by comparing nutrient release rates to standard inorganic fertilizers, providing practical insights into their contribution to soil nutrient replenishment over time. This review highlights the potential of organic amendments to substitute or complement chemical fertilizers, emphasizing the need for targeted application based on crop-specific nutrient demands and the distinct nutrient release dynamics of each organic source.

Key words: Nutrient release pattern, mineral fertilizer equivalent, organic source, compost, N, P and K

Introduction

Modern agriculture mainly involves the use of chemical fertilizers for supplying essential nutrients to crop plants. However, an excessive use of chemical fertilizers often results in poor soil physical conditions and low microbial activity ultimately degrading soil quality which in turn has deleterious effects on sustenance of soil productivity. The use of organic manures in addition to chemical fertilizers is, therefore, recommended in many developing countries for achieving sustainable food production without endangering soil quality and environment. A sound soil fertility management program requires a precise assessment of nutrient supply from each component of nutrient cycle for developing an efficient integrated nutrient supply system.

Mineralization is a process of conversion of unavailable organic forms of nutrient to the plant available inorganic form (Tisdale *et al.*, 1997). Soil organic matter releases substantial quantities of nitrogen, phosphorus, sulphur and little amount of micro-nutrients upon mineralization (Rahman *et al.*, 2013; Amanullah 2007). Mineralization of nutrients from the applied manure depends on the type of soil, soil moisture and temperature regimes, manure characteristics and microbial activity in the soil, *etc.* (Moorhead *et al.*, 1996). Since the effect of these factors cannot be accurately quantified, the mineralization of nutrients from the organic amendments can only be approximated. To efficiently utilize the macro and micro nutrients from organic manures, the mineralization potential of each organic amendment needs

to be assessed and considered while deciding their application rates (Eghball *et al.*, 2002).

Manures are known to have residual effect on nutrient supply for two or more crop seasons. However, very limited information exists about the release of plant nutrients from different organic amendments. Mineralization of N from organic manures has been studied and modeled by several researchers (Abbasi *et al.*, 2007). The availability of P, K, S and micro-nutrients from organic manures needs to be assessed for effective utilization of these organic nutrient sources in crop production (Villegas Pangga *et al.*, 2000). The information is important for farmers to reduce their sole dependence on costly chemical fertilizers and may help them to adopt integrated plant nutrient supply system approach using the most efficient organic manure/amendment for supplying critical nutrient to achieve the sustainability of the production system and also to ensure good soil health. The farmers practicing organic mode of cultivation can suitably option for a combination of varying doses of different organic amendments to maintain the soil fertility.

Factors Affecting Decomposition

1. **Temperature:** Cold periods retard the organic matter decomposition and there will be more accumulation of organic matter on the top soil compared to that of warm climates. The most suitable temperature is 30-40°C for proper decomposition.
2. **Soil moisture:** Near or slightly wetter than field capacity moisture conditions are most favorable for decomposition. About 60-75 % water holding capacity (WHC) is optimum.
3. **Soil pH:** 6-8 pH or neutral pH is required for optimum growth of microorganisms. Bacteria at 6-7 pH, Actinomycetes is more at pH 8-10, Algae pH of 5.5-7.5, Fungi- pH 4.0, Protozoa – pH 3.0.
4. **Nutrients:** Lack of nutrients, particularly N reduces microbial growth and it slows decomposition. Addition of nutrients by N fertilizers (urea) increases the speed of decomposition.
5. **Soil texture:** Soils higher in clays tend to retain larger amounts of humus, other condition being equal.
6. **Aeration:** Good aeration increases the rate of decomposition and supply oxygen.
7. **Nature of plant matter:** composition and age

of plants and vegetations affect much their decomposition. It is fast in young, tender, and juicy material, but slow with more cellulose and hemicelluloses content.

Assessment of Nutrient Release Pattern

$$\text{Dry mass remaining \%} = \frac{W_t}{W_0} \times 100$$

Where,

W_t = Weight remained after each sampling (g) and,

W_0 = Initial weight (g)

$$\text{Nutrient remaining \%} = \frac{W_t}{W_0} \times \frac{C_t}{C_0} \times 100$$

Where,

W_t = Weight remained after each sampling (g) and,

W_0 = Initial weight (g)

C_t = Concentration of element in decomposing litter at the time of sampling

C_0 = initial concentration of element

Mineral fertilizer equivalent

MFE gives an indication of the utilization of organic fertilizers compared with mineral-fertilizer N and enables comparisons of the N availability for different organic fertilizers in different years and on different soils (Thomsen, 2004).

For example, the application of 100 kg N via an organic fertilizer with an MFE value of 30% will result in the same crop uptake N as that of 30 kg of mineral-fertilizer N.

$$\text{MFE \%} = \frac{N_{of}}{N_{mf}} \times 100$$

Where,

N_{of} - the crop N uptake in the treatment with organic-fertilizer application

N_{mf} - N uptake in the treatment with mineral-N application, both corrected for the N uptake from a control treatment (no N application to quantify N uptake from soil N mineralization).

Nutrient Release Pattern of Different Organic Sources

Reizig *et al.*, (2014) demonstrated that combining mineral fertilization with crop residues (RF + CR) significantly enhanced decomposition and nutrient release compared to other treatments. The half-life ($t_{0.5}$) values indicated that the RF + CR treatment led to the fastest decomposition (6.70 weeks), followed by sewage sludge

(SS) (8.0 weeks), crop residues alone (CR) (9.60 weeks) and the control (C) (11.91 weeks). After 12 weeks, the RF + CR treatment showed the lowest percentage of remaining dry matter (53.85%), indicating the most rapid breakdown. Nitrogen release was also most efficient with RF + CR, with 50% N loss occurring after just 5.04 weeks, compared to 6.47 weeks for SS, 7.53 weeks for CR, and 8.88 weeks for the control. By the end of the experiment, only 29.81% of the initial N remained in RF + CR, compared to higher amounts in the other treatments. Phosphorus release was slower, but RF + CR again led the way, with 50% P loss at 8.41 weeks, faster than SS (9.75 weeks), CR (10.91 weeks), and C (16.83 weeks). Potassium release was even more rapid, with RF + CR reaching 50% K loss in just 5.51 weeks. Calcium and magnesium release followed similar patterns, with RF + CR decomposing 50% of the initial content by 7.37 and 4.41 weeks, respectively, outperforming other treatments in terms of nutrient release speed. The lower amounts of residual nutrients in RF + CR across all measured elements highlight its superior ability to promote nutrient cycling and enhance soil fertility.

Bloukounon-Goubalan *et al.*, (2019) investigated the mineralization rates of organic carbon, nitrogen, phosphorus, potassium, calcium and magnesium in various manures, including poultry, pig, and mixtures of these with cow and sheep manures. Poultry manure exhibited the fastest OC and N mineralization, with half-life of 31 and 34 days, respectively, while pig manure had the slowest rates (half-life of 135 days for OC and 103 days for N). Phosphorus mineralization was highest in the poultry-pig manure mixture (half-life 50 days) and slowest in the poultry-sheep mixture (140 days). Potassium mineralization was rapid across all manure types, with half-life ranging from 24 to 38 days. Ca mineralization was highest in the poultry-pig mixture, and Mg mineralization was fastest in the poultry-cow mixture.

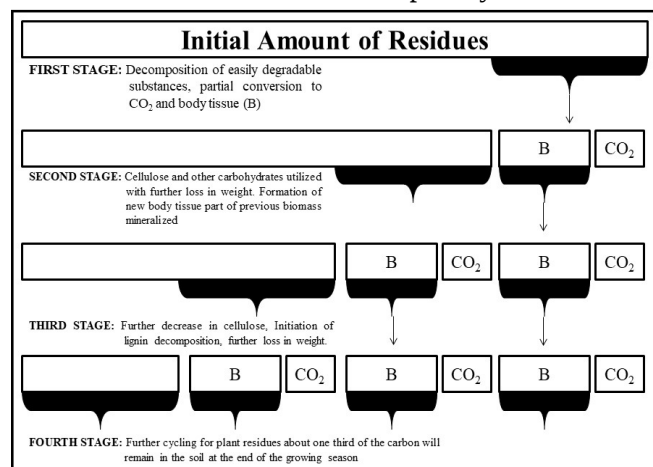


Fig. 1: Stages of Decomposition of Organic Residues.

Table 1: Week required for 50 % nutrient release from different organic sources.

Nutri- ents	Reizig <i>et al.</i> , (2014)	Bloukounon- Goubalan <i>et al.</i> , (2019)	Dey <i>et al.</i> , (2019)
N	5.0-8.9	4.6-37.5	-
P	8.4-16.8	6.6-18.7	23.6-33.4
K	5.5-13.3	3.2-5.1	9.7-15.6
Ca	7.4-15.9	9.3-25.7	18.7-84.3
Mg	4.1-9.3	4.3-10.1	17.1-53.3
S	-	-	27.4-110.8
Fe	-	-	17-30.6
Mn	-	-	14.8-18.6
Zn	-	-	13.1-21.1
Cu	-	-	16.8-90.8
B	-	-	9-58

The study found that nutrient release followed the general order of $N < P < K$, with variations depending on the manure type. These findings highlight the potential of poultry manure for quick nutrient release and the benefits of combining manures to optimize nutrient availability for crops.

Dey *et al.*, (2019) evaluated the release of key nutrients from various organic amendments over a 120-day incubation period. Phosphorus release ranged from 23.6% in biochar (BC) to 36.1% in farmyard manure (FYM), with biogas slurry (BS) and poultry manure (PM) showing the highest P release. For potassium, BC and FYM released the most, with K release percentages between 52.8% (vermicompost, VC) and 82.3% (BC). Calcium release was highest in BS (40.9%) and lowest in BC (9.6%), while magnesium release was led by BS (48.9%) and lowest in mushroom compost (MC) at 16%. Sulphur release followed the trend: FYM (39.2%) > PM > MC > BS, with biochar showing the least release. For trace elements, BS and PM had the highest zinc release, ranging from 38.2% in PM to 62.3% in BS. Copper release was also highest in BS (49.9%) and lowest in PM (8.6%). Iron release varied less across treatments but was highest in BC (47.5%) due to its reducing agents. Manganese release was most significant in MC (51.2%) and lowest in BC (41.9%). Boron release was notably high in PM (97.7%) and BC (56.6%). Overall, BS and PM showed superior nutrient release, making them highly suitable for improving soil fertility, especially for P, Ca, Zn, and Cu. Biochar was particularly effective for K and Fe release, despite its slower rates for other nutrients. These findings emphasize the importance of selecting organic amendments based on specific crop nutrient needs.

Kiboi *et al.*, (2020) conducted an experiment in two

seasons [SR16 (short rains season from late October to December) and LR17 (long rains season lasting from March to June)], two sites with Conventional Tillage (ConvT) and Minimum Tillage (MinT) for 12 weeks and they observed that nutrients' release rates in *T. diversifolia* (Mexican Sunflower) were significantly higher under ConvT by 57 and 48% for N and P, respectively, compared with MinT on the 6th week during SR16 season in Meru South. At Kandara site, N release rates from animal manure were significantly higher under ConvT by 60% on the 2nd week and 30% on the 8th week compared with MinT during SR16 season. The phosphorous release rate was significantly high under ConvT by 62% on the 2nd week, 43% on the 8th week and 25% on the 10th week during SR16 season. During LR17 season, N and P release rates in animal manure were significantly higher under ConvT by 54% compared with MinT on the 8th week at Kandara. Nitrogen release rates from *T. diversifolia* were significantly higher under ConvT by 40% on the 4th week, 30% on the 6th week and 42% on the 10th week during SR16 season. P release rate from *T. diversifolia* was significantly higher under ConvT by 41% on the 4th week and 32% on the 10th week compared with MinT. During LR17 season, N and P release rate from *T. diversifolia* was significantly higher under ConvT by 29 and 28% respectively, compared with MinT on the 8th week.

Mineral Fertilizer Equivalent (MFE) of Different Organic Sources

Guster *et al.*, (2005) observed that among all organic sources' poultry slurry recorded higher nitrogen short term mineral fertilizer equivalent (N-MFE) followed by meat/ blood/bone meal. They observed lower short-term N-MEF in biocompost. Poultry slurry has a higher N-MFE due to its high nitrogen content and the presence of readily

Table 2: Nitrogen mineral fertilizer equivalent (MFE) of different organic sources.

Organic sources	NMFE (%)	Reference
Biocompost	0-20	Guster <i>et al.</i> , (2005)
Solid manure	10-20	Guster <i>et al.</i> , (2005)
Green manure	10-40	Guster <i>et al.</i> , (2005)
Thick sewage sludge	15-30	Guster <i>et al.</i> , (2005)
Thin sewage sludge	45-55	Guster <i>et al.</i> , (2005), Delin <i>et al.</i> , (2012)
Brewery/distillery residues	30-35	Guster <i>et al.</i> , (2005)
Cattle slurry	35-45	Guster <i>et al.</i> , (2005), Delin <i>et al.</i> , (2009)
Legume coarse meal	35-45	Guster <i>et al.</i> , (2005)
Biogas residues plant biomass	40-60	Guster <i>et al.</i> , (2005), Delin <i>et al.</i> , (2012)
Biogas slurry	50-74.19	Guster <i>et al.</i> , (2005), Delin <i>et al.</i> , (2012), Devi <i>et al.</i> , (2020)
Meals of horns, feather and leather	50-70	Guster <i>et al.</i> , (2005), Delin <i>et al.</i> , (2012)
Dried poultry excrements	60-70	Guster <i>et al.</i> , (2005)
Meat/ blood/ bone meal	57-80	Guster <i>et al.</i> , (2005), Delin <i>et al.</i> , (2012)
Poultry slurry	70-85	Guster <i>et al.</i> , (2005)
FYM	52.71-82.76	Shah & Ahmad (2006), Azam <i>et al.</i> , (2009), Devi <i>et al.</i> , (2020), Tiwari <i>et al.</i> , (2020)
Poultry manure	66.95	Azam <i>et al.</i> , (2009)
Filter cake	55.94	Azam <i>et al.</i> , (2009)
Rapseed cake	36	Delin <i>et al.</i> , (2012)
Pig Slurry	52	Delin <i>et al.</i> , (2012)
Chicken manure	49	Delin <i>et al.</i> , (2012)
Horse meal	6	Delin <i>et al.</i> , (2012)
Vermicompost	78.86-82.52	Wagh <i>et al.</i> , (2014), Devi <i>et al.</i> , (2020)
Neem cake	83.44	Wagh <i>et al.</i> , (2014)

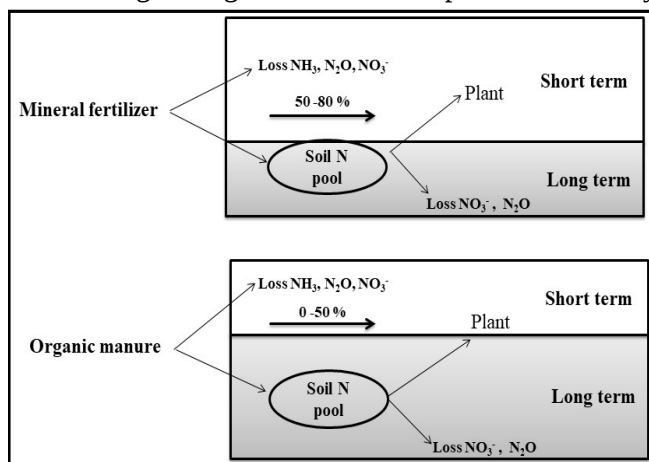


Fig. 2: Schematic overview on short and long-term effects of mineral fertilizer and organic manure on soil N availability. [Guster *et al.*, (2005)].

available forms of nitrogen, while biocompost has a lower N-MFE because its nitrogen is bound in more stable, organic forms that release nitrogen more slowly.

Shah and Ahmad (2006) found that N fertilizer replacement value in wheat by FYM is 82.76 % but when FYM was applied with the combination of inorganic fertilizer then its MFE % was increased as compared to the it's alone application. The increase in MFE when FYM is combined with inorganic fertilizer occurs because the readily available nitrogen from the inorganic fertilizer complements the slow-release nitrogen from FYM, improving nitrogen use efficiency, reducing nitrogen losses

and enhancing overall nutrient availability and plant growth.

Azam *et al.*, (2009) recorded that N fertilizer replacement value was higher in the FYM (70.75 %) as compared to the poultry cake (66.95 %) and filter cake (54.94 %) but when organic sources were applied with the combination of inorganic fertilizer then its MFE % was increased as compared to their alone application. The increase in MFE when organic sources like FYM, poultry cake and filter cake are combined with inorganic fertilizers is primarily due to the complementary nitrogen release patterns, improved nitrogen use efficiency, enhanced microbial activity and a more balanced nutrient supply. These factors lead to better overall nitrogen availability, reduced nitrogen losses and improved plant growth, resulting in higher nitrogen fertilizer replacement values compared to the application of organic sources alone.

Brod *et al.*, (2012) evaluated different organic sources for their N-MEF and they concluded that the N-MEF also depends on dose of application of manure *i.e.* higher the dose of organic manure, lower the N-MFE%. It might be due to applying higher doses of organic manure reduced nitrogen mineralization efficiency, increased nitrogen immobilization, potential nutrient imbalances and higher nitrogen losses through leaching or volatilization.

Delin *et al.*, (2012) reported higher N-MFE in blood meal followed by feather meal and biogas residues. Comparatively lower N-MEF was reported in horse meal, rapeseed cake, cattle and pig slurry. The higher N-MFE in blood meal, followed by feather meal and biogas residues, is due to their high nitrogen content, simpler organic structures and faster nitrogen mineralization. Horse meal, rapeseed cake, cattle and pig slurry have lower N-MFE due to their lower nitrogen content, more complex organic forms and slower nitrogen release.

Brockmann *et al.*, (2014) observed that among different application methods of organic manures, the higher N-MFEs were obtained in deep injection method as compared to broadcaster and trailing shoe methods. It might be due to deep injection method reduces nitrogen losses through volatilization, runoff and leaching, places nitrogen closer to the root zone for better uptake and enhances microbial activity for efficient nitrogen mineralization. This results in more nitrogen being available to plants, leading to improved N-MFE compared to surface application methods like broadcasting and trailing shoe.

Wagh *et al.*, (2014) observed that N fertilizer replacement value was higher in the neem cake (83.44 %) as compared to the vermicompost (82.54 %) but when

these organic sources were applied with the combination of inorganic fertilizer then its MFE % was increased as compared to their alone application in okra.

Delin (2016) observed higher P-MFE in biogas residues applied in rye grass followed by wheat straw ash and oat grain ash, chicken manure and cattle slurry. The higher P-MFE in biogas residues applied to ryegrass compared to other organic sources is primarily due to the availability and concentration of phosphorus in biogas residues, their effective interaction with soil and plant systems and the overall nutrient dynamics associated with different organic amendments.

Devi *et al.*, (2020) noticed that improved FYM by waste decomposer had higher nitrogen MFE % than the vermicompost, FYM, mushroom compost and biogas slurry. However, they also observed that when these organic sources applied with the combination of inorganic fertilizer then their N MFE % was increased. Similarly, Tiwari *et al.*, (2020) found that 52.71 % nitrogen replacement value of FYM but when it applied with inorganic fertilizers the N-MEF increase.

Conclusion

Nutrient release from the organic sources depends on the rate of its decomposition. Nutrient release and MEF depends on C:N ratio, lignin and cellulose content in organic sources. Further, nutrient release and MEF also depends on environmental conditions as well as physical chemical and biological properties of soil. Overall, 50% release of nutrients from organic sources required approximately 3 to 111 weeks. Among the nutrients, K (3 to 16 weeks) take less time and S (27 to 111 weeks) and Cu (17 to 91 weeks) take comparatively more time for releasing. Similarly, fertilizer replacement value of different organic sources is in the range of 10-85% of the chemical fertilizers even in long term basis.

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