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REVIEW PAPER

A discussion on integrated effect of compost and urea fertilizer on growth and yield of crops: An updated review

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Abstract

The degradation of soil fertility presents a significant hurdle in maintaining agricultural production across many nations. Sole reliance on either inorganic or organic fertilizers can yield both advantageous and detrimental impacts on plant growth, nutrient availability, and soil health. Integrating organic waste and compost into agricultural practices stands as a key approach to harnessing valuable sources of organic matter (OM) and nutrients, thereby promoting sustainable agricultural methods. Moreover, the enhancement of composts with chemical fertilizers can significantly boost the agronomic efficiency by decreasing the required fertilizer quantity while simultaneously elevating the compost quality. While organic fertilizer can improve soil physical and biological activity, it has a lower nutrient content, requiring larger quantities for plant growth. On one hand, inorganic fertilizers provide an immediate and rapid supply of essential nutrients directly available to plants. However, the continual use of inorganic fertilizers results in the depletion of soil organic matter, increased soil acidity, and environmental pollution. Therefore, an integrated nutrient management system serves as a viable approach for cost-efficient and sustainable soil fertility management. This system involves the combination of both inorganic and organic materials to enhance soil fertility and productivity without causing detrimental environmental impacts. This study aims to assess the effects of blending compost with urea fertilizer on specific aspects of soil fertility and productivity. The findings indicate that a strategic combination of organic and inorganic fertilizers enhances productivity without compromising yield quality. Moreover, it significantly boosts soil fertility beyond what can be achieved by using either organic or inorganic fertilizers separately. Additionally, enriched compost reduces application rates from tonnes to kilograms per hectare, reducing dependence on chemical fertilizers to a certain extent. This farmer-friendly approach is economically acceptable and environmentally sustainable as it reduces compost application rates, saves N fertilizer, and recycles organic waste while potentially reducing N losses to the environment.

Keywords: Compost, Growth, Inorganic, Nitrogen, Nutrients, Organic, Pollution, Yield

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Introduction

To promote continuous crop cultivation, a combination of organic and inorganic fertilizers can be used to enrich the soil and improve its chemical and physical status, resulting in higher crop yield (Basso & Ritchie, 2005). Both categories serve as valuable reservoirs of essential mineral elements vital for the optimal growth and development of plants. The crucial mineral elements required for optimal plant growth fall into two categories: micronutrients and macronutrients. Their presence in specific quantities is vital. Among these, nitrogen, phosphorus, and potassium stand out for their pivotal roles in plant growth and development. An imbalance in these elements can significantly impact crop yield. Nitrogen, an integral part of chlorophyll, fosters vegetative growth and the vibrant green hue of foliage (Jones, 1983). Phosphorus, on the other hand, is crucial for various fundamental processes like photosynthesis, respiration, energy storage, cell division, and overall maturation. Potassium is a pivotal element in plant metabolism, contributing significantly to protein synthesis and the formation of chlorophyll essential for plant development (Remison, 2005). Within agricultural systems, the key crop nutrients considered most crucial are nitrogen (N), phosphorus (P), and potassium (K) (Chude et al., 2004).

The search for sustainable options for managing degraded land has become increasingly significant due to the rapid decline in soil fertility, a prevalent issue in arable land. Enhancing soil nutrients through fertilizer application is a crucial strategy in agriculture. However, the exclusive reliance on inorganic fertilizers is not popular among farmers due to their detrimental environmental impact, including soil acidification, water pollution, scarcity, and high costs. In Pakistan, the challenge of depleted soil fertility hinders in achieving higher crop yields, as most cultivated soils contain less than 1.5% organic matter, and the addition of organic matter remains limited. Consequently, many farmers heavily depend on chemical fertilizers to address nutrient deficiencies and secure profitable yields, leading to a lack of organic matter accumulation in the soil. According to Nambiar (1997), the combined use of organic manure and chemical fertilizers shows promise not only in ensuring more consistent production but also in preserving better soil fertility status. Long-term research reveals that the application of dung manure at 5 tons per hectare per year significantly improves soil conditions, preventing degradation (Bhuiyan et al., 1994). Goyal et al. (1992) found that combining farmyard manure (FYM) or sesbania green manure with urea resulted in increased yields of pearl millet (*Pennisetum glaucum*), nitrogen uptake, and nitrogen recovery after a four-year study, compared to the use of urea alone. Janzen and Schaalje (1992) discovered that applying green manure plus fertilizer to barley resulted in double the losses of fertilizer N than when solely using green manure. This was attributed to high levels of nitrate and available C promoted by green manure, which improved denitrification. However, a shift to smaller, repeated applications of green manure led to reduced losses, indicating that incorporating high-quality green manure as a partial substitute for inorganic fertilizer, rather than just an addition, could enhance nutrient utilization efficiency. Similarly, Ganry et al. (1978) concluded that substantial application of low-quality straw might result in notable losses of fertilizer nitrogen due to denitrification (Shah & Khan, 2003). These findings suggest that nitrogen losses from both organic and inorganic sources can be considerable, challenging the widespread belief that utilizing organic resources would lead to lower losses."

The incorporation of organic materials, whether independently or combined with inorganic fertilizers, contributes to sustaining adequate soil nutrition and fertility (Talashiker & Rinal, 1986; Salim et al., 1988). According to Hussain et al. (1988), the efficiency of chemical fertilizers can be improved by adding organic manures. Farmyard manure has been shown to have beneficial effects on crop production by improving soil fertility and physical properties (Singh & Sarivastore, 1971). In a recent field experiment in Peshawar Valley, Shah and Ahmad (2006) found that the combined application of urea and farmyard manure (FYM) in 75: 25 ratio produced the highest crop and nitrogen yields in wheat. Composting is a process that biodegrades organic waste into stable and humified material using a mixture of microbes under controlled conditions of moisture, temperature, and aeration. The resulting organic matter can be applied to land without any environmental impact (Lasaridi & Stentiford, 1999; Tuomela et al., 2000; Eghball et al., 2004; Paredesa et al., 2005) and used as a source of nutrients for sustainable crop production. Composted organic material reduces the need for inorganic fertilizers and can improve soil physico-chemical properties and OM status (Harmsen et al., 1994; Alvarenga et al., 2007; Ahmad et al., 2008). The use of organic fertilizers has become more prevalent globally as renewable energy sources and cost reduction in crop fertilization have become essential. Incorporating mature compost at appropriate quantities has been shown to improve plant growth, enhance soil physical properties, and elevates soil nutrient levels (Ahmad et al., 2008; Zafar et al., 2011). Therefore, to sustain crop production in depleted soils, a balanced integration of organic sources (from both plant and animal origins) with inorganic nutrient sources is necessary.

Use of organic fertilizer

The application of organic fertilizers involves the use of naturally occurring organic sources derived from both plant and animal origins, such as livestock manure, green manures, crop residues, household waste, and compost that can directly provide essential nutrients to plants and indirectly impact soil physical, biological, and chemical properties The application of organic fertilizers involves the use of naturally occurring organic sources derived from both plant and animal origins, such as livestock manure, green manures, crop residues, household waste, and compost that can directly provide essential nutrients to plants and indirectly impact soil physical, biological, and chemical properties (Ngoc Son et al., 2004). The breakdown of organic fertilizers by soil microorganisms makes nutrients available for plants, exhibiting slow-release characteristics (Amujoyegbe et al., 2007). The incorporation of organic fertilizers is known to enrich soil biological activity, fostering the symbiotic relationship between mycorrhizae and higher plants. Moreover, these fertilizers encourage root development by enhancing soil structure and promoting the creation of soil aggregates, and increasing the soil's cation exchange capacity (Lal, 2006). These organic fertilizers also serve as a stabilizing agent, helping to maintain a balanced soil pH and prevent unwanted fluctuations (Olaniyi & Ajibola, 2008).

Inadequately processed organic fertilizers pose a risk by potentially harboring harmful pathogens that can affect both human health and plants. This risk stems from the origin of organic fertilizers, often derived from materials such as animal waste or plant/animal matter, which might be tainted with pathogens (Chen, 2008; GTZ, 2009). Moreover, organic fertilizers generally possess a lower nutrient concentration, necessitating a larger volume for adequate nutrient supply for plant growth. This aspect poses a significant challenge in large-scale agriculture where the exclusion of inorganic fertilizers is pursued (Vanlauwe et al., 2010). An additional hurdle associated with organic fertilizers is their variable composition, making it complex to accurately tailor nutrient applications that align with plant requirements. While microorganisms are essential for breaking down organic matter and releasing nutrients into the soil, their effectiveness is contingent on warmth and moisture. Consequently, the seasonal limitations of warmth and moisture restrict the optimal functioning of organic fertilizers (Chen, 2008; GTZ, 2009).

Enhanced soil fertility and sustainable agriculture practices

Various research studies have highlighted the decline of nutrients in organic soil, primarily attributed to factors such as the extraction of essential elements like nitrogen, potassium, and phosphorus through livestock grazing and the removal of crop residues. Although these nutrients can be reclaimed through byproducts such as manure, the reintegration of manure into farming and grazing lands faces obstacles as it is frequently utilized as a fuel source. For instance, in Ethiopia, an estimated 22.5 million tons of cattle manure are generated annually, with a substantial 38% being used as fuel. Correspondingly, about 21.2 million tons of crop residues are produced each year, of which 24% is utilized as fuel, while the remaining 76% is either consumed by livestock or left on the ground (Erkossa et al., 2004). This extensive practice contributes to the deterioration of soil quality, resulting in a decline in nutrient levels. In situations where soil quality significantly diminishes, the application of chemical fertilizers might become necessary. These fertilizers can swiftly re-establish soil fertility, making essential nutrients promptly available to plants once dissolved in the soil (Matsumoto & Yamano, 2009). Furthermore, the use of inorganic fertilizers has been observed to enhance root residues, indirectly leading to an increase in organic matter (Scholl & Nieuwenhuis, 2004). Consequently, farmers have begun to emphasize the use of inorganic fertilizers to enhance agricultural productivity.

Inorganic fertilizers offer significant advantages in promoting rapid plant growth due to their immediate solubility in water, ensuring a noticeable and instantaneous effect. They contain all necessary nutrients in appropriate quantities, demanding only small amounts for optimal productivity. Additionally, the judicious application of inorganic fertilizers can augment soil organic matter by boosting root mass and crop residues (Scholl & Nieuwenhuis, 2004; Chen, 2008; GTZ, 2009). However, the overuse of synthetic fertilizers can lead to unfavorable outcomes such as leaching, water contamination, soil acidification, and diminished accessibility of trace elements or soil alkalinity. Overuse can further accelerate the decomposition of soil organic matter, leading to soil structure degradation and reduced soil aggregation, resulting in nutrient loss due to fixation, leaching, and gaseous emissions, ultimately diminishing fertilizer efficiency. Furthermore, excessive application of synthetic fertilizers can result in detrimental impacts on soil quality, human well-being, and the surrounding ecosystem as evidenced by studies conducted by Gruhn et al. (2000); Abedi et al. (2010).

Soil fertility through integration of organic and inorganic fertilizers

Maintaining optimal soil fertility levels using solely organic resources necessitates a considerable quantity of organic fertilizer per field. Conversely, exclusive reliance on inorganic fertilizers may result in immediate high crop yields, but it can detrimentally affect soil structure, organic matter content, and the overall environment (Chen, 2008; GTZ, 2009). In response to these challenges, the synergistic application of organic and inorganic fertilizers emerges as a practical strategy to enhance soil fertility and productivity. This combined approach emerges as the most effective method to elevate soil productivity and fertility while also curtailing expenses (Mungai et al., 2009; Bodruzzaman et al., 2010) and mitigating the adverse impacts associated with the excessive use of chemical fertilizers.

Crosstalk between combined use of organic and inorganic fertilizers

Sustaining agricultural productivity in Ethiopia faces a substantial challenge due to low soil fertility. Human interventions such as improper land use practices, reliance on monoculture, and continuous nutrient depletion, coupled with insufficient nutrient replenishment, have notably aggravated this predicament. To alleviate the problem of soil fertility, integrated nutrient management (INM) can be used to sustainably produce agricultural products by utilizing both organic and inorganic nutrients. Therefore, a study was conducted to assess the impact of integrated nutrient management (INM) practices on maize yield and soil fertility enhancement over a three-year period (2001 to 2003) in the acidic Alfisols of Bako Agricultural Research Center, located in western Ethiopia. The findings revealed significant variations in both maize grain yield and plant height across all treatment groups during various cropping seasons, except in the year 2002. As a result, the study inferred that employing integrated nutrient management (INM) along with FYM or a reduced amount of NPK fertilizers can effectively enhance both maize yield and soil fertility in the western region of Ethiopia (Wakene et al., 2007).

In a controlled experiment following a randomized block design at Tamil Nadu Agricultural University, Coimbatore in 1972, researchers investigated the impact of continuous utilization of organic and inorganic fertilizers on the micronutrient composition of an Inceptisol. The study aimed to assess the effect on the growth of finger millet, maize, and cowpea (fodder) in a sequential cropping pattern while using varying doses of N, NP, NPK with FYM for finger millet and Zn for maize. Over a span of 25 years, significant trends emerged: a distinct decrease in DTPA-Zn levels was observed, while there was an evident rise in the Fe, Cu, and Mn content within the topsoil. The introduction of $ZnSO_4$ for maize cultivation led to an augmentation in the available Zn content in the soil. Furthermore, employing 100% NPK in combination with FYM resulted in increased DTPA-Fe, Cu, and Mn concentrations. Although there were no significant variations in micronutrient availability among the different levels of NPK, it was evident that the control plot exhibited lower micronutrient availability (Selvi et al., 2002).

In a field trial conducted on sandy clay loam soil, Khalid et al. (2004) investigated the impact of farmyard and poultry manure along with urea on two different corn hybrids namely Pioneer 3062 and Pioneer 3012. Their findings revealed that Pioneer 3062 demonstrated superior performance compared to Pioneer 3012 in terms of grain yield, 1000-grain weight, and the number of cobs per plant. However, there were no significant differences observed in terms of harvest index or the number of grains per cob between the two hybrids. Notably, the combination of poultry manure and urea application resulted in the most effective outcomes compared to all other treatments. Ayoola and Makinde (2007) explored the influence of both organic and inorganic fertilizers on the growth and yield of a cassava/maize/melon intercrop, incorporating relayed cowpea. Their research revealed that a combined application of 200 kgha^{-1} NPK 15-15-15, 2.5 t ha^{-1} year^{-1} poultry manure and decomposed urban refuse (in a 1: 1 ratio by weight) delivered the most favorable outcomes for maize growth and yield. Shah and colleagues (2007) executed a field study in the Peshawar valley of Northwest Frontier Province, Pakistan, during the summer of 2005 to explore the impact of a combination of compost and urea on both maize yield and nitrogen uptake. Their investigation examined various ratios of nitrogen supply from these sources (0: 0, 100: 0, 75: 25, 50: 50, 25: 75, and 0: 100). The findings demonstrated that the most substantial biological and grain yields for maize were achieved when the nitrogen supply comprised a 75: 25 ratio of urea to compost. The subsequent highest yield resulted from the treatment with an equal split of 50% nitrogen from urea and 50% from compost. Conversely, lower yields were evident in treatments where the proportion of nitrogen from urea fell below 50%. Moreover, the nitrogen uptake in both grain and stover was notably higher in treatments where 75% of the nitrogen originated from urea and 25% from compost, compared to other fertilizer treatments. These findings strongly advocated for the combined use of urea and compost as an integrated approach to enhance both crop yields and nitrogen uptake in maize.

Amujoyegbe and colleagues (2007) carried out a study at the Teaching and Research (T&R) Farm of Obafemi Awolowo University in Nigeria to investigate the impact of replacing soil with organic fertilizer (poultry manure) and inorganic fertilizer on the yield and chlorophyll levels of maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* (L.) Moench). Comparatively, the control plot exhibited the least chlorophyll contents in both maize and sorghum. Shah et al. (2009) carried out an experiment at the Agronomic Research Area, University of Agriculture, Faisalabad, aimed at investigating the impact on the growth and yield response of maize concerning different sources of nitrogen (both organic and inorganic). The study involved the application of farmyard manure at a rate of 15,000 kg/ha and urea at a rate of 260 kg/ha on sandy clay loamy soil fertilizing two maize varieties: Composite-78 and Composite-79. The two maize varieties exhibited significant disparities in various parameters related to growth and yield including plant height, the number of cobs per plant, grains per cob, 1000-grain weight, grain yield, and harvest index. These differences highlighted distinct responses of the maize varieties to the varied nitrogen sources applied. Composite-78 outperformed Composite-79 in all growth and yield parameters, except for plant density and the count of plants bearing cobs. The simultaneous application of urea and farmyard manure resulted in the highest grain yield, reaching 6.13 tons ha^{-1}.

Rahman et al. (2012) conducted a study at the On Farm Research Division (OFRD) farm in Rangpur between 2002 and 2005 to explore the impact of combining inorganic fertilizers with organic manure and mungbean residue on both soil characteristics and crop yield. Their research revealed that employing a combination of manure and inorganic fertilizers based on an integrated plant nutrient supply (IPNS) model resulted in maize seed yields comparable to those achieved using chemical fertilizers alone, irrespective of whether the goal was moderate or high yield. Treatment T5 demonstrated the highest maize yield at 10.02 tons per hectare, significantly surpassing all other treatments. The growth of mungbean was encouraged by temperature and rainfall, resulting in low pod formation. However, combining Sesbania biomass and mungbean residue, when used in combination with inorganic fertilizers to achieve a moderate yield goal (MYG), demonstrated equivalent grain yields to the results obtained using fertilizers alone for a high yield goal (HYG) in T. Aman rice cultivation. Notably, the integrated plant nutrient supply (IPNS) dhaincha treatment exhibited the highest grain yield of 4.31 tons per hectare for the high yield goal (HYG). Throughout the growth period, there were no significant alterations observed in the soil's status. Consequently, incorporating mungbean residues or Sesbania biomass before planting T. Aman rice could significantly enhance crop productivity and uphold soil fertility. Ahmad et al. (2013) conducted an experiment aimed at exploring the impact of combining organic and inorganic fertilizers in a low-fertility soil at the Agricultural Research Institute in Tarnab and Peshawar. The findings indicated that the integration of organic sources with 50% of the recommended NPK fertilizers resulted in the highest grain and biological yields for maize, surpassing the yields from the treatment using only 50% NPK. Moreover, these integrated yields were statistically comparable to those achieved with 100% NPK fertilizers. Similar trends were observed concerning leaf area index and grain harvest index. Additionally, the combination of organic sources with 50% of the recommended NPK fertilizers led to the highest net return. Furthermore, Ahmad et al. (2006) highlighted that fruit and vegetable wastes (FVW), characterized by a high C: N ratio, might impact nitrogen availability to crops when directly applied to agricultural soils due to nitrogen immobilization during the decomposition process. They suggested that converting organic waste into a value-added soil amendment via composting, by blending it with nitrogen, can enhance the efficiency of nitrogen fertilizer while reducing potential environmental hazards associated with these organic wastes.

Conclusion

The process of composting and adding lower doses of urea N can convert organic waste materials into valuable organic fertilizer. Using a combination of organic and synthetic fertilizers can lead to higher crop yields compared to using them individually, while also reducing the buildup of organic waste and improving soil organic matter. By diminishing the need for mineral N fertilizers, there is a reduction in the utilization of non-renewable energy sources and pollution from greenhouse gas emissions and nitrates in groundwater can be minimized. This holds particular significance for farmers with limited resources, particularly those in developing nations such as Pakistan, who may have limited agricultural incomes. In order to increase soil fertility and food production, it is critical to create an enabling environment that addresses constraints that hinder compost production and enhances connections between individuals in rural and urban areas to produce top-quality compost. Comprehensive research and development initiatives are essential to address deficiencies in organic fertilizers and explore approaches to enhance soil fertility including methods like crop rotation, green manuring, and efficient crop residue management. Precise evaluation of plant health through methods such as chlorophyll fluorescence or hyperspectral imaging is crucial to determine the effectiveness of organic fertilizers. Adapting smallholder agriculture to tackle climate change, combat soil degradation, and mitigate rising costs of mineral fertilizers by promoting the use of organic alternatives stands as a sustainable solution to guarantee food security.

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