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Mixing Manure with Chemical Fertilizers, Why? and What is After?

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Abstract

Using chemical fertilizers or organic manure alone as amendments may bring negative effects to the quality of crops. Neither of these alone can sustain productivity. Hence, judicious uses of organic manure with chemical fertilizers are essential to augment productivity of crops. Scattered references can be found in this paper on the effects of the integrated use of organic manure and chemical fertilizers on cultivation of crops. How this particular fertilization treatment affects the changes in physical properties of the soil, water use efficiency, nitrogen use efficiency and plant growth is also being covered. This paper is to review the importance of organic manure application with chemical fertilizers in crop production. Also, we unravel the works of others on different types of crops that showed positive correlation with the use of organic manure with chemical fertilizers.

Keywords: Organic manure; Farmyard manure; Chemical fertilizers; Yield; Crops

Introduction

Combination organic manure and chemical fertilizers: Revolution in agriculture activities

During the last decades, agricultural activities have vastly grown resulting in the application of different chemical and organic fertilizers. People mainly in horticulture production are in dilemma on which type of fertilizer to be applied on their crops. This is due to the advantages and the downside of using organic and chemical fertilizers. Both organic and chemical fertilizers have different effects on soil, crops, and nutrient availability. In the end it all falls down to the individual himself to decide on which fertilizer to use for better crop yield. It is necessary to develop alternative nutrient management practices to maintain soil health in order to increase productivity and crop yields. Nutrients and minerals must be available in balanced quantities for optimum plant growth. Natural reserves of plant nutrients in soils are released too slowly to meet crop requirements. Hence, Chen [1] believes that fertilizers are created to provide nutrients already present in the soil. In Bangladesh, the deterioration of soil fertility due to the increasing land use intensity without proper use of chemical fertilizers with no organic manure is a major constraint for higher crop production [2]. As fertile soil is important for a higher crop production, its maintenance is a necessity for long-term sustainable crop productivity. The key factor to crop productivity and sustainable soil fertility is soil organic matter.

With the release of N, P, S and micronutrients, organic matter undergoes mineralization. It can be said that the reason behind the declination of important component in soils with time is due to rigorous cropping and excessive doses of chemical fertilizers with no addition of organic manure [2]. Organic manure application with chemical fertilizer is crucial to sustain and enhance the soil fertility. This can be supported with a statement made by Nambiar [3] that it would be promising to provide greater stability in production and maintain better soil fertility by using organic manure with chemical fertilizers. A combination of organic and inorganic source of

nutrients is essential to ensure high quality food production for sustainable agriculture [4]. Ali et al. [2] also believed that it is crucial to integrate the use of organic manure with chemical fertilizers in order to sustain the yield of crop without affecting soil fertility.

Moreover, the integrated use of organic manure and chemical fertilizers also increases fertilizer use efficiency [5]. Due to the benefits of integrated use of organic manure and chemical fertilizers to crops yield, it is therefore suggested that the combined use of organic manure with chemical fertilizers be applied continuously. Rabindra et al. [6] report supporting evidence that physicochemical properties of cane yield, juice quality and soil are improved with continuous application of farmyard manure along with chemical fertilizers. In the case of sugarcane, for its sustainability and sugar production, chemical fertilizers and organic manure could not stand-alone but the combined used of these two is highly beneficial [7]. In this paper, an attempt has been made to bring together various findings related to the use of integrated organic manure and chemical fertilizers on the yield of crops and some concluding observations in the last section.

Why organic manure?

Farms produce large amount of manure. Intensive livestock production causes the disposal of these wastes as one of environmental problems. A number of approaches have been practiced for the beneficial use of manures. Some of the examples are composting, land application, and use as amendments in plants. By using organic manures as organic fertilizer, agriculture can benefit from these manures and this can be a cheap way for society to conserve the environment. What makes organic manures favorable to be used, as fertilizers are the high organic matter, nitrogen content contents and other plant nutrients [8]. The positive outcomes of the application of organic manure to soil organic matter quantity are well established. The word 'manure' is originated from the Latin word, 'manu' that means 'hand' and operate which means 'to work'. Prices for chemical fertilizers are increasing in developing countries hence it is difficult to rely on the sole use of chemical fertilizers. In addition, it is of growing

concerns for maintaining soil productivity that has led to the use of organic manure as well. The application of organic manure is believed to be important in soil fertility [9]. This can be seen in a study made in Japan that the application of organic matter to crop has improved root growth and nutrient uptake resulting in higher yields [10]. Organic fertilizer especially from animal byproduct contains high level of nutrients, organic matter content, and a variety of micronutrients [11]. Organic manure is essential to replenish organic matter content and not just supplying plant nutrients of most agriculture soils especially in the tropics [12]. The soil quality could be improved with the application of organic manure and is more profitable in the environment protection in contrast to the application of chemical fertilizers alone [13]. It has been exhibited in most cases that the application of decomposed farmyard manure could increase the yields of crops grown on saline [14]. For example, when organic manure is incorporated into the soil irrigated with saline water, it will increase the concentrations of nitrogen and potassium in the soil [15]. Liang et al. [16] also reported that the application of pig manure or rice straw increased the biomass of barley and rice because of enhancement of soil fertility in a rice-barley rotation system. Although manure contains various micronutrients, the nutrient composition of farm manure varies depending on species of animal, exposure, aging and moisture content. The nitrogen in manure is tied up in organic form making it unavailable to growing plants in the first year. Organic nitrogen is available to plants when soil microorganisms decompose organic compounds for example proteins and undergoes a process called mineralization (convert the release N to NH_4^+) [17]. The approximate percentage of organic N mineralized in the first year application from different types of animals is shown in table 1. From table 1 we can see that the amount mineralized in the first year relies on the manure source.

Why composted manure?

The livestock industry activity has intensified which generated vast amount of biodegradable wastes. Hence, a proper disposal management needs to be carried out to avoid a negative impact on the environment. Composting is deemed fit to counter this problem as it comes with environmental profits since the process involves eliminating the risk of spreading pathogen, weeds and parasites associated with direct application of manure and leads to a final stabilized product that can improve and maintain soil fertility [18]. Composting is an economical and effective way to treat animal manure for land application. This is because pathogens and weed seeds are destroyed and the heterogeneous solid-state organic matter is transformed to more stable humic substance by the activity of bacteria [19]. In addition, nitrogen concentration of the original waste is reduced during composting and nitrogen is transformed into stable forms whose plant availability is reduced. This can be seen when uncomposted manures nitrogen mineralization rates of 38%-60% were reduced to 6%

Manure source	Percent of organic N mineralized
Beef	35%
Dairy	35%
Horse	20%
Sheep	25%
Swine	50%
Poultry	35%

Source: Nebraska Cooperative Extension Bulletin EC89-117, Fertilizing Crops With Animal Manure.

Table 1: Approximate percentage of organic N mineralized in the first year application

20% upon composting [20]. Due to high moisture contents, high density of animal manure and low C/N ratio, bulking agents are needed to modify the properties of animal during composting. Compost quality is referred to stability and maturity of compost [21]. The microbial activity is typically referred to as the stability and can be defined by the respiration index or the conversion of chemical species in compost organic matter [22], while the amount of degradation of phytotoxic organic substance is referred to maturity and is measured by plant bioassays or germination index [23]. It can be said that a stable compost when added to soil as an organic amendment improves the functionality of soil. An evidence to support this statement is a finding by Piccolo et al. [24], regarding plant, growth and soil fertility can be improved when stable and mature compost is added to soil as an organic amendment. For a compost to be safely used in soil, it needs a high degree of stability and maturity which means stable organic matter content and the absence of phytotoxic compounds and plant or animal pathogen. Immature composts cause problems during storage and use. This is because during storage these materials develop anaerobic "pockets" that cause pungent smell and development of toxic compound [25]. One of the environmental advantages of compost as a soil amendment is the decreased mineralization rates may reduce the nitrate leaching potential by delaying the conversion of organic N to mobile nitrate N [26]. It is also believed that nitrate leaching could be reduced by replacing chemical fertilizer with compost in vegetables studies [27]. In a nutshell, composted animal manure is important prior to land application.

Why not plant based fertilizer?

A study made by Raupp and Oltmanns [28] based on the last crop rotation (2002-2005) showed that organic carbon content of plant based fertilizer is lower (0.74%) compared to farmyard manure which is significantly higher (0.78%). He also stated that the carbon input provided by plant based fertilizer was not effective enough to sustain soil organic matter content over the years. Another evidence that plant based fertilizer is not preferable over organic manure can be seen in a study where potatoes fertilized with faba bean meal had lower K contents compared to those fertilized with farmyard manure [29]. They also claimed that the higher humus content was found with farmyard manure even at normal rate. Hence, it is still uncertain whether plant based fertilizer is able to maintain the soil fertility in the long run.

Effects of organic and chemical fertilizers on soil microorganisms

Microorganisms play important roles in ecological functions of soils, such as nutrient cycling and degradation of organic pollutants.

Biological fertilizer can enhance soil microbial activity of the soil, such as improving the activity of soil enzymes and increasing soil microbial biomass [30]. In a long-term field experiment, Mäder et al. [31] showed that soils under organic farming regime had higher microbial functional diversity than those under the conventional farming system.

Synthetic fertilizers are essential for nourish plants and microbes but may have harmful effects on the soil, especially when they are very concentrated and water-soluble. Chemical fertilizer may help soil life, and soil life helps fertilizers and their availability for plants and microbes [32].

Chemical fertilization had resulted in crop yield increase; it was not sufficient to trigger a significant change in the soil microbial properties [33]. Kong et al. [34] concluded that the continuous application of chemical fertilizers for 13 years did not cause a significant change in the soil microbial biomass and the functional diversity of the black soil.

Application of animal manure with chemical fertilizers

Organic fertilizers which are from animal byproduct and crop residues contain high level of nutrients, organic matter content, and a variety of

micronutrients [11] which are used as fertilizers for organically grown fields. The soil quality could be improved with the application of organic manure and is more profitable in the environment protection in contrast to the application of chemical fertilizers alone [13]. Organic matter inclusion in the form of farmyard manure has proven to enhance soil structure and water retention [35], decrease bulk density [36] and increase infiltration rates [37]. However, the supply of plant available nitrogen deficiency from organic fertilizer which is due to slow rate of mineralization lowers crop yields compared to those treated with chemical fertilizer [38]. Neither organic nor inorganic amendments alone are able to maintain organic matter status of soil and maintain the productivity in semi-arid tropics [39].

A combined application of organic and inorganic sources of nutrients is important to maintain soil health and improve nutrient efficiency [40]. Conacher and Conacher [13] also supported this statement mentioning that organic manure application with chemical fertilizer could maintain soil nutrient balance, enhance nutrient availability, improve soil chemical and physical properties, increase soil organic matter, reducing fertilizer loss rate and improve soil fertility and ecosystem productivity. There were other reports on combined organic and inorganic fertilization showing that both enhanced C storage in soils and decrease emissions from N fertilizer use [41]. The method of applying combined organic manure and inorganic fertilizers as a total basal dressing is useful to the balanced nutrient release and reduction of N loss, which increased the N use efficiency [42]. In China, the combined application of commercial organic manure and inorganic fertilizers proved to be an effective way to fertilize plants [43]. The nutrient removal and by crops and the addition of nutrient to soil from fertilizers or manure are crucial in the nutrient balance of a cropping system [44]. Generally, the immobilization and mineralization of N can be affected by the application of manure, which promotes the release of soluble P and speeds up the process of the release of structural K causing it to be closer to that needed by the crops [45]. They also believe that the application of organic manure is more profitable in environment protection and could enhance soil quality compared with chemical fertilizer application alone. Hence, this will eventually increase crop production.

Experimental outcomes of the application of organic manure combined with chemical fertilizers

Rice: Based on a study made by Xu et al. [5] during six years of fertilization there were significant correlations between cumulative yield of rice and time showing that in all treatments there was the same trend of cumulative yield increasing with years. The highest cumulative yield could be seen in chemical fertilizers (NPK) application with pig manure followed by application of chemical fertilizers alone and lastly, application of pig manure alone. The yield composition varied among the treatments. The treatment with application of chemical fertilizer combined with organic manure had larger total panicles and filled grains per panicle. It is also proven that nitrogen use efficiency is greatly improved in the application of chemical fertilizers combined with animal manure. In terms of soil organic matter, it was improved with the application of organic manure combined with chemical fertilizer and simultaneously enhanced soil fertility. The combination of chemical fertilizers and organic manure could increase rice yield by adjusting the rate of nutrient release in soil and fertilizer [46].

Soybean: A study by Bandyopadhyay et al. [47] showed that mixed use of farmyard manure (cow dung) and chemical fertilizer improved soil organic carbon content compared to the use of chemical fertilizer (NPK) alone. Swarup [48] also concluded that the use of farmyard manure with chemical fertilizer in soybean-wheat system, from 25 years of continuous cropping in long-term experiments, significantly enhanced soil organic carbon content in Haplustalf and Chromustert. Under mixed use of NPK

and FYM, bulk density was lower than the application of chemical fertilizer alone. The reduction in the bulk density is probably due to high soil organic carbon content of soil [49]. The increased grain yield of soybean was exhibited in the annual application of FYM along with recommended dose of chemical fertilizers. The higher grain yield of soybean in NPK with FYM is attributed to better water and nutrient utilization and root growth. Bhattacharyya et al. [50] prove this finding with findings. FYM and NPK integrated to enhance the N uptake by soybean grain and resulted in high water use efficiency. As for the root, such integrated is essential for better penetration and establishment of soybean roots that allows the plants to use water from deeper layers and to sustain high relative plant moisture content under a condition of soil moisture stress that is familiar in rain-fed farming [51].

Sweet maize: Experimental studies by Efthimiadou et al. [52] showed that poultry/cow manure combined with chemical fertilizer resulted in high increase in total soil N. Moreover, it is believed that maize crop is more stable under combined organic and inorganic fertilization treatment compared with inorganic fertilization alone. The application of organic manure and chemical fertilizers in this experiment promoted plant growth (dry, height, weight and leaf area index) compared to mineral fertilized. Furthermore, the stomatal conductance and photosynthetic rate of combined organic and inorganics fertilization treatments were high. Plus, the crop yield is also promoted with this fertilization treatment. This finding is in agreement with that one of Kimeto et al. [53]. That a combination of chemical fertilization and organic nutrient source gave maize higher yield than when applied separately. A similar study by Zhao et al. [54] found that farmyard manure application with chemical fertilizer causes higher yield in maize, available N, soil organic matter, and available P compared with those found under mineral fertilizer treatment.

Dates: A field study carried out by Marzouk and Kassem [55] found that the application of chicken manure combined with chemical fertilizers and cow dung combined with chemical fertilizers resulted in higher yield than application of mineral N alone. This finding is supported by earlier studies on the importance of adding organic matter with mineral fertilizers for larger yields of date palms [56]. In this study, the fruit diameter, fruit weight, fruit colour, fruit size, fruit dry matter content, total sugar and anthocyanin content improved significantly by using a combination of organic manure and chemical fertilizers. Al-Kharusi et al. [57] also attain the highest dry matter content in Khalas and Khassab dates by applying the combined organic manure with chemical fertilizers. In addition, the nutrient uptake by plants and the overall crop yield have been proven to increase when the mineral fertilizers were added with organic fertilizers [58].

Tomato, radish and pakchoi: Experimental studies on tomato, radish, and pakchoi by Lu et al. [59] showed that tomato fruit yield, radish and pakchoi market yields were the highest in commercial organic manure (matured pig manure) application with chemical fertilizer compared to other treatments. It is believed that commercial organic manure used as partial substitute for chemical fertilizers could sustain the market yields of tested vegetables crops. Generally, by applying manure, it can affect immobilization and mineralization of N, thus promote the release of soluble P and speeds up the process of structural K release, making it closer to that needed by the crops [45]. Partial substitution of commercial organic manure application for chemical fertilizers was seen as a beneficial approach to meet the nutrient need and sustain yields of radish-tomato-pakchoi crops with comparison of using chemical fertilizers alone.

Sugarcane: A study by Bokhtiar and Sakurai [60] on the integrated use of organic manure combined with chemical fertilizers on the crop production, i.e., growth, yield, and quality of sugarcane indicated that

treatments are getting organic manure produced taller than chemical fertilizers only. It is believed that the increased tiller population is because of the integrated use of organic manure with chemical fertilizers is better than the utilization of any of the amendments alone. The leaf area index in treatment with mixed use of farmyard manure and chemical fertilizers was found maximum compared to others. Additionally, 25% of chemical fertilizers could be saved by the use of organic manure as full rates or 25% less chemical fertilizers with farmyard manure at 15t ha⁻¹ as the cane yield of those two was statistically at par. As for the sugar yield, the highest could be seen in treatment with integrated use of organic manure and chemical fertilizers.

Conclusion and Future Prospective

Therefore, it can be concluded that integrated use of organic manure and recommended dose of chemical fertilizers resulted in significant improvement in crop yields and quality despite being an active practice in nutrient management. Organic manure used with chemical fertilizers can maintain crop yield and meet the nutrient requirements to grow. Using organic manure from castoff and applying it in an intensive cropping system can be considered as an essential measure to decrease the potential risk of water pollution caused by castoff. Composted manure can also be used for the combination use of organic manure and chemical fertilizers to replace fresh manure to reduce environmental pollution without affecting the crops nutritional quality. In sustainable agriculture, the integrated use of organic manure and chemical fertilizers is necessary to create a healthy soil environment in the long run. This method produces a significant yield of crops compared to the application of organic manure or chemical fertilizers alone. Hence, combining the use of organic manure with chemical fertilizers is the right approach to sustainable agriculture.

Application of microbial-based fertilizers has been increasing worldwide due to the recognition of the deleterious effects generated by the excessive and improper use of chemical fertilizers. Designing of bio-fertilization programs, each with specific useful features best suited for the different growth stages of the crop, similarly done with chemical fertilizers, would also improve their use.

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