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Effect of Organic Fertilizers on Maize (*Zea mays* L.) Production and Soil Physical and Chemical Properties

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Abstract: Organic fertilizers can improve soil physical properties such as structure and aggregation, water holding capacity and drainage and chemical properties such as nutrient holding capacity through increased cation exchange capacity and increased ability to resist changes in soil pH. Improvement in soil physical and chemical properties can improve plant growth and yield. Several research studies were done on the effect of organic fertilizers on crop yield and soil properties. However, organic fertilizers are not widely used in intensive arable agriculture, due to some limitations. Therefore, this review paper was aimed at revising and compiling previous work on the effect of different organic fertilizer on maize yield and soil physiochemical properties.

Key words: Maize · Organic Fertilizer · Soil · Yield

INTRODUCTION

Maize (*Zea mays* L.), sometimes called as corn is the most significant cereal crop in sub-Saharan Africa (SSA). It is a main staple food and plays an important role in reducing poverty and improving the food security in SSA [1]. Maize serves as food, feed as well as industrial raw materials and contains up to 80% carbohydrate in form of starch and 10% crude protein [2]. Maize is a source of nutrients as well as phytochemical compounds such as carotenoids, phenolic compounds and phytosterols which play a significant role in preventing chronic diseases [3, 4]. Despite its nutritional and economic value, its production is far from crop potential. This low yield can be caused by several constraints and mainly by low soil fertility [5].

Application of fertilizers to increase crop yields is much known. However, the use o f inorganic fertilizer by resource poor farmers is limited by its scarcity and cost [6] and untimely availability [7]. Besides excessive use of inorganic fertilizer in continues cropping system can lead soil, water and air pollution [8-11]. The use of organic amendments such as farm yard manure, poultry manure, crop residue and compostis an alternative to these harmful effects of inorganic fertilizers due to its wide-spread availability, its additional value for soil organic carbon and its ability for storing and releasing nutrients over a longer time period [9]. Application of organic fertilizer could increase the yield through enhancing soil fertility and nutrient use efficiency [12]. Several research findings showed the advantage of application of organic manures on improving soil physical properties, water holding capacity and organic carbon content besides supplying nutrients to the plant. Therefore, this review paper was aimed at revising and compiling previous work on the effect of different organic fertilizer on maize yield and soil physiochemical properties.

Effect of Poultry Manure on Growth and Yield of Maize: Among organic manures, poultry manure is highly nutrient-rich organic manure. The addition of poultry manure will provide sufficient amount of micronutrients for crop growth [13]. Poultry manure decomposes faster than other animal manure, such as cattle or pig dung; thus it releases its nutrients for plant uptake and utilization rapidly [14]. Further, Khalil *et al.* [15] stated that poultry manures do not contain lignin, unlike crop residue. As a result, their decomposition is relatively fast and they release a high concentration of organic acid which increase N uptake and N availability in the soil and also improve grain yield. The study done by Farhad *et al*. [16]

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showed that addition of poultry manure at different rates improved the yield of maize over the control and application of 5t/ha of PM gave a higher yield of maize. Poultry manure also increased the grain yield, leaf area and total relative chlorophyll content of maize and sorghum [17]. Similarly, Law-Ogbomo *et al.* [18] reported that the highest grain yield (5.77 t ha^{-1}) and 1000-grain weight of maize were found from application of 5.0 t ha^{-1} of PM, this indicating the best PM level for maize growth and yield in the rainforest Ultisol.

Poultry manure also increased uptake and concentration of N, P, K, Mg, Ca, Zn, Fe and Cu of maize besides improving soil nutrient [19]. Saravanane *et al*. [20] reported a 7.62% increase in seed yield of maize with the application of poultry manure. Mbah and Onweremadu [21] stated that poultry manures provided the highest grain yield by enhancing aggregate stability and diminishing bulk density showing that these factors added to final grain yield. Phosphorus in the manure also plays a key role in plant P nutrient [22, 23].

The application of poultry manure is the most practical technology to maintain soil fertility but the effects on crop yield are slow compared to the use of chemical fertilizer. Because of this farmers are reluctant to use this technology as they need to see quick results [24]. Also, it has been reported that poultry manure as a sole fertilizer is inadequate to sustain crop production. For instance, it was reported that the addition of 5 t/ha of poultry manure was able to sustain moderate yields of maize as low as 2 t/ha. Poultry manure was able to meet the requirement for N but it was inadequate to meet the P requirement in low P areas [25].

Effect of Farmyard Manure on Growth and Yield of Maize: Farmyard manure (FYM) has a high proportion of organic material that nurtures soil organisms and is essential in maintaining an active soil life. FYM contains all the macro- and micronutrients essential for plant growth, but its main effect is due to nitrogen, phosphorus and potassium [26]. The efficiency of manure utilization by a crop is affected by the method of application, time to incorporation and the rate of decomposition in the soil. Application of FYM alone or in combination with inorganic fertilizers benefits in proper nutrition and improve soil fertility when applied at proper. According to Flaig [27], application of FYM can maintain soil productivity longer than inorganic fertilizers.

Shah *et al*. [28] reported that the application of nitrogen through FYM at 1.5 t/ha and urea at 260 kg/ha gave the highest grain yield of maize with in comparison to the rest of the treatments. Similarly, Masood *et al*. [29] reported that short-term application of higher FYM amount increases the nutrient uptake of maize plants, improves soil properties and the availability of water to large extent. Zerihun *et al*. [30] also reported that the application of FYM at a rate of 12 t ha^{-1} gave optimum yield and net profit with the highest rate of return as compared to 8 and 16t ha^{-1}.

The study conducted by Achieng *et al*. [31] to evaluate the effect of FYM and inorganic fertilizers on maize yield. The result showed that FYM gave significantly the same plant population, plant height, cob number, 100-seed weight, Stover and grain yield as with other treatments. However, FYM increased grain yield 103% and 108% over farmer's treatment in Ultisols and Alfisols, respectively. They also reported that under dry season FYM had a 4% grain yield advantage over optimal and NPK treatments.

Eleduma *et al.* [32] reported that cattle manure significantly improved the performances of maize and soil fertility. The highest yield attributes such as the number of grains, cob length, grain weight and husk weight were obtained at a rate of 20 t ha^{-1}, but cattle manure applied at the rates of 10 and 5 t ha^{-1} did not significantly different from control treatment. The increased maize growth and yield with respect to increasing the application rate of cattle manure might be due to the availability of balanced nutrients to the crop that resulted in a favorable soil environment. They suggested application of 20 t ha^{-1} for adoption by resource-poor farmer as substitute for chemical fertilizer, consequently lessen environmental pollution modeled by the discarding of the cattle waste and eventually improve yield.

Effect of Crop Residues on Growth and Yield of Maize: Crop residues are part of the plant that left on the field after the harvestable parts of the crops (grain, tubers, roots, etc.) have been removed. Crop residues had considered as waste materials that require disposal, but it has gained attention as an important natural resource [33].Crop residues are the main source of plant nutrients and recycled nutrients to the soil when they have decomposed. Incorporation of crop residues to the cropland can sustain soil organic carbon, maintain soil fertility, moderate soil temperature and increase soil microbial activity [34]. Crop residues especially from leguminous plants, have a great nitrogen benefit and nitrogen recoveries, not just satisfy the N requirement of the subsequent crops, additionally expanding the long-term soil productivity [35]. Phoomthaisong *et al.* [36]

stated that tthe incorporation of leguminous crops in the cropping systems has the ability of enhancing the nitrogen content of the soil by fixing nitrogen from the air, thus improving the productivity of the cereal. Noack *et al.* [37] also reported that crop residues contain inorganic and organic P forms, easily available for plants and microorganisms.

Crop residues contain a significant amount of nutrients and can be effective ways of sustaining soil organic matter and soil nutrients. When crop residue is incorporated into the soil from where it grows and properly managed, it can be a potential source of nutrients [38]. Plant residues contains even to eight times greater quantity of nutrients compared to the amount of nutrients added as inorganic fertilizers and also it contains micronutrients which are not found in inorganic fertilizers [39]. Proper management of crop residues could, therefore, reduce the use of costly chemical fertilizers and improve the crop productivity and alleviate water and nutrient stress [40]. However, in most African countries the farmers used crop residue as fodder, fuel or construction material, thus minimizing the retention of crop residue.

The complete removal of crop residues can drain the nutrient stock, reduce soil organic matter content and degrade soil physical properties [41]. Therefore, in most African countries the nutrient balances in the soil are negative, where the removals of nutrients are greater than the added nutrient, showing nutrient mining [42]. For instance, in Ethiopia, complete removal of crop residues from the land is estimated to remove the major nutrients (N and P) in the order of 255 to 800 kg/ha equivalent of urea and triple superphosphate ha^{-1} $year^{-1}$, respectively [43]. Crop residues contain about half of the nutrients that are taken up by the plant from the soil [44]. Therefore, recycling of crop residue must be a major part of the approach to decrease the nutrient losses in low input agriculture. Nevertheless, crop residues alone are inadequate to balance nutrient losses and increase crop yield in most of developing countries [45]. Therefore, integrated application of organic (crop residue and manure) and inorganic fertilizer is the best option to sustain soil fertility and crop productivity.

Almaz *et al*. [46] revealed that application of soybean and maize + soybean residue without or with inorganic fertilizers increased maize yield and enhanced grain quality of maize (Table 1). However, incorporation of maize residue alone without supplemental inorganic fertilizer was ineffective in increasing grain yield and quality (protein sugar and oil content) of the maize crop above that of control. The same authors reported non-significant yield difference between application of soybean residue with supplemental phosphorus and potassium fertilizer and complete NPK fertilizer application. They conclude that inorganic nitrogen fertilizer can be replaced with soybean residues without any reduction in maize yield and grain quality. Similarly, Sinha *et al.* [47] reported that incorporation of crop residues on soil increased the grain and straw yield, compared with the residues removed treatments. Bakht *et al*. [48] also revealed increased shoot biomass with residues incorporation.

Effect of Green Manure on Growth and Yield of Maize: Green manure have several advantages including, regulating soil surface temperatures due to their high surface ground, increasing soil organic matter content to the soil thus improving soil physical properties, controlling soil erosion and conserving soil moisture during some parts of the year [49]. Gachene *et al*. [50] reported that green manure have the advantage of improving soil fertility as well as soil moisture conservation especially in the semi-arid environments. The use of green manure legumes (GLM) as cover crops in rotation with maize has the potential to enhance maize yields [51]. Gachene *et al*. [50] observed 16-58% increment of maize yield during the subsequent seasons after incorporating the green manure residues.

Akundabweni *et al*. [52] observed that mucuna green manure applied at a rate of 120 kg N ha^{-1} significantly improved maize grain yield in both short and long rain seasons when rainfall amounts received were variable. However, application of mucuna green manure at higher rates of 240 and 480 kg N ha^{-1} resulted in no further significant increase in maize grain yield. Mureithi *et al*. [53] also reported application of 1.0 t DM ha^{-1} of mucuna green manure equivalent to 27 kg N ha^{-1} failed to show significant increase in maize yield on a nitisol in central Kenya. Tanimu *et al*. [54] noted that a predictable consequence of the variable N quantities, in different application rates is that they will contribute varying amounts of the nutrient to the soil and this is likely to be reflected in the crop.

Studies conducted in Uganda showed that green manure such as, *Crotalaria ochroleuca* can increase maize yield by 39% [55]. Ojiem *et al*. [56] reported that in Kenya, averaged over two years, green manure such as, *Crotalaria ochroleuca* and *Mucuna pruriens* improved maize grain yield by 1.5 t ha^{-1} compared to control or no incorporation. Similarly, in Tanzania, farmers have used sun hemp to increase their maize yield from 12.4 to 45 bags ha^{-1} [57].

Table 1: Effect of organic manure residues and inorganic fertilizer on yield characteristics of maize

Treatment	Green cob yield (kg/ha)	Biological yield (kg/ha)	Protein content (%)	Sugar content (^{0}brix)	Oil content (%)
Control	10, 323e	18, 527e	8.30e	9.00d	4.77d
100% NPK	37, 290a	47, 545a	15.2ab	15.4a	6.00abc
Maize residue	11, 237e	21, 377e	11.1d	10.9c	4.77d
Maize residue + 100% PK	20, 217c	30, 037c	12.9c	12.8b	5.63d
Soybean residue	17, 173d	28, 528c	13.8bc	13.3b	5.30cd
Soybean residue + 100% PK fertilizers	36, 500a	44, 550a	16. 5a	16.3a	6.30ab
Maize +soybean residue	14, 020g	24, 122d	13.2c	11.0c	4.90d
Maize + soybean residue + 100% PK	29, 620b	38, 958b	14.0bc	15.1a	6.67a

(Source: Almaz *et al*., [46])

Effect of Organic Manure on Soil Fertility: Long-term soil fertility is threatened by enhancing soil organic matter levels to certain level, providing crop nutrient directly, soil biological activity by soil micro-organisms, nitrogen through the biological nitrogen fixation [58] and recycling of nutrients and organic materials animal manure [59]. Continuous application of inorganic fertilizers along with continuous cropping causes soil degradation owing to loss of organic matter. The outright use of inorganic fertilizers to bring about better crop production had a negative effect on the soil. This might be due to crop response to applied fertilizer depends on soil organic matter [60]. Organic fertilizers comprised of decomposed essential elements in an unequal proportion [61] and showed a strong positive effect on moisture holding capacity and structure of the soil [62].

Wang *et al.* [63] reported that addition of organic fertilizer into the soil can significantly increases oil pH by about 0.04. This is ascribed to higher concentrations of basic nutrients in organic amendments and hydrous oxides reduction in soils [64]. Similarly, Mbagwu and Ekwealor [65] found that the decrease in bulk density found with poultry manure treated soil was directly related to improved organic matter which played a significant role in reducing compaction of soil. Being a source of organic matter, the organic amendments promote soil faunal activity and play a major role in the buildup and stabilization of soil with structure. The significant decrease in soil bulk density could be attributed to the direct and indirect effect of soil amended organic matter (SOM) levels. Directly, OM due to its low bulk density and ability to increase soil aggregate stability results in lower soil bulk density and soil compatibility. Indirectly, the decrease in bulk density improves structure and is partly substantiated by enhanced total porosity.

According to the study conducted by Mugnai *et al*. [66], the application of compost increased soil levels of organic matter and nitrate, compared with mineral fertilization. Similarly, Hossain *et al.* [84] reported that bio waste and food waste in-crease pH, nitrogen content, cation exchange capacity, water holding capacity and microbial biomass in soil. This might be due to it contains various amounts of organic matter and huge amounts of plant nutrients. Manure is a common waste which improves soil properties by adding nutrients and increases microbial and enzyme activity in soil. It also reduces toxicity of some heavy metals. These organic wastes have a great positive impact on soil physical, chemical and biological properties as well as stimulate plant growth and thus increase the yield of crops [67]. Jedidi *et al.* [68] and McGeehan [69] also reported the positive effects of organic waste on soil. Organic sources of P are more effective for plant uptake compared to inorganic fertility sources [70], this is because of availability of phosphorus from all animal manures is high (> 70%). Kleinman *et al*. [71] stated that adding high soluble P quantities brings the soil to saturated conditions and a fraction of the added P remains in the available form.

The study conducted by Nemera *et al*. [72] showed that application of cattle manure gave higher available phosphorous due to the fact that cattle manure is rich in phosphorous, potassium, magnesium and calcium and the significant proportion of phosphorus in manure mineralize slowly and gradually to release plant available phosphorous The increased amount of available phosphorus after harvest observed in cattle manure application treatments also might be attributed from the release of soluble humic material or organic acids from the decomposing of the organic residues and manures contribute greatly to decrease P adsorption capacity and increased available P that occurs in soils [73]. Nest *et al*. [74] reported that after a long-term (40–50 years) experiment with manure application, extractable P was increased 2–4 times if compared to a mineral P fertilizer application. The same authors proved the application of manure to be more effective in increasing soil pH and P availability than the mineral fertilizer. Similarly, CEC and buffering capacity were increased with the addition of manure to soil, but Fe and Ca contents were not influenced by manure application [75].

Table 1: Nutrient composition (on an as is basis) and dry matter content of select animal manures and agricultural by-products that can be used as organic fertilizer

	Composition (%, as is)			
Material	N	P	K	Dry matter (%)
Manure				
Beef cattle	0.57	0.14	0.41	8
Dairy cow	0.52	0.12	0.36	13
Poultry-broilers	3.08	1.28	1.82	74
Poultry-layers	1.68	1.06	1.20	42
Swine-grow-finish	0.93	0.31	0.48	11
By-products				
Alfalfa meal	2.77	0.25	2.46	90
Cottonseed meal	7.38	1.16	1.65	92
Rice bran	2.30	1.73	1.89	91

[Source: Green, [78]

Limitation of Organic Fertilizer Application: The application of organic manures for agricultural purposes has many advantages, but also have some disadvantages or limitation for adoption in large particularly in Africa. Organic manures have very long term effect on the soil because nutrients are released very slowly. Only one-fifth of the nutrients supplied by animal manures are recovered by the first-crop following the application. Much of the remainder is held in humus-like compounds subject to very slow decomposition. In these forms, the elements are released only very slowly, rates of 2-4% per year being common. Thus, the humus-like compounds in manure will have continuing effects on soils years after their. According to Wheeler [76], farmers have faced several problem for using organic fertilizer such as nutrients in organic manure are so low (Table 1) that a huge quantity of manure has to be added for the desired dose of nutrients, transport of a huge quantity of manure to the site of application is difficult and the rate of mineralization and the rate of release of nutrients, particularly of the nitrogen, is slow, labour intensive, limited sources of manure, higher cost of organic fertilizer, storage of manures and emergence of weeds and unfavorable smell of most of organic fertilizers. Lack of skills and technical knowhow are also limitations in the use of organic fertilizers [77].

Chen [79] stated that long-term or heavy application to agricultural soils may result in salt, nutrient or heavy metal accumulation and may adversely affect plant growth, soil organisms, water quality and animal and human health. Similarly, Scotti *et al*. [80] reported that addition of organic waste increased t soil salinity due to decomposition of wastes, this is because of direct solubilization of ions that released soluble mineral nutrients in soil. Nest *et al.* [74] also reported that the addition of manure to soil prompted significant P leaching.

Song *et al*. [81] revealed that crop yields under application of organic manure are lower than under inorganic fertilizer due to a slower release of nutrients and the out-of-proportion NPK content. The author further explained that to achieve high yields and a high economic output, the heavy application of organic manure has been adopted in China. Consequently, excess fertilization under organic farming is frequently observed, especially in vegetable greenhouses. The excessive application of fertilizer and manure has increased soil P levels in many areas [82, 83]. Whalen *et al*. [84] reported that only one-quarter to one-third of the P fertilizer is utilized, while large amounts of P accumulate in the soil. Excessive P can lead to plant toxicity and the immobilization of trace metals in the soil, as well as ground and surface water pollution through runoff. Since, P is immobile element, it is important to understand the forms and characteristics of P in soil for developing long-term management strategies.

CONCLUSION

Organic fertilizers include a variety of plant-derived materials that range from fresh or dried plant material to animal manures and litters to agricultural by-products. Organic fertilizer is an excellent soil amendment that provides a balance of nutrients while contributing valuable organic material to the soil. The soil application of manure has a positive impact on soil physical and chemical properties and improved the grain yield of maize. However, organic fertilizer has low nutrient content and applied huge amount, this makes cost ineffective to transport organic fertilizer to the long distances. Therefore, use of locally available sources is perfectly reasonable if its use is consistent with the production strategy.

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