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Research Article
Morphological, Yield and Yield Components of Maize (*Zea Mays* L.) Grown in Cattle Manure Amended Soil in the Jordan Valley

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Abstract

Background and Objective: Intensive cropping systems in Jordan valley demand high amounts of chemical fertilizer application to the soils which results in degradation of the soil organic matter and cause water impurity. The objective of this study was to investigate the effects of cattle manure at various rates on maize (*Zea mays* L.) growth and development. **Materials and Methods:** A field trial was conducted at the National Center for Agricultural Research and Extension in the Jordan Valley, Northwest of Amman, Jordan, during summer 2015. Six soil treatments were compared using randomized complete block design with 4 replications: No cattle manure (T1) control, 4 t ha^{-1} (T2), 8 t ha^{-1} (T3), 12 t ha^{-1} (T4), 16 t ha^{-1} (T5) and 20 t ha^{-1} (T6) cattle manure. The morphological parameters measured were plant height, stem and ear diameters, ear length, plant and ear numbers, yield and yield components of maize. Treatment means were compared using least significant difference ($p<0.05$). Treatment combinations were organized in a randomized complete block design (RCBD) with 4 replications. **Results:** It was found that 20 t ha^{-1} cattle manure (T6) gave the highest performance in terms of plant height, stem and ear diameters, ear length, plant and ear numbers, yield and yield components of maize. **Conclusion:** The study revealed the importance of cattle manure in producing organic maize with high productivity.

Key words: Cattle manure, chemical fertilizers substitutes, harvest index, morphological parameters, *Zea mays*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Jordan Valley is considered the main source of food and particularly vegetables and grains in Jordan as a result of its favorable environmental conditions and water availability. Maize is a vital crop for Jordanian people, who use its grains as a food and its stover as animal feed. Maize (*Zea mays* L.) is known to have developed in Mexico over 7000 years ago from a wild grass, following which Native Americans transformed it into a better source of food. Maize comprises approximately 75% starch, 11% protein and 5% fat, however, it has lower protein content than rice (*Oryza sativa*) and wheat (*Triticum aestivum*)[1]. Maize is widely dispersed crops being planted all over the world. However, USA, China and Brazil are the three main maize-growing countries, together producing approximately 563 of the 717 million metric t grown each year[2].

Maize is a basis of many vitamins (e.g., some of the B-group vitamins) and essential minerals, in addition to fiber, but lacks some other nutrients, such as vitamin B12 and vitamin C and is, in general, a poor source of calcium, folic acid and iron[1,3]. Processed maize recycled in many foods and processed products, such as alcohol and ethanol fuel. Maize is also recycled to create industrial ethanol, increasing the demand for this crop and driving up its price for both animal and human consumption. Consequently, lower costs of production, in addition to a higher depletion of maize flour and corn food, particularly in regions where micronutrient deficiencies are common, will help to support food availability and solve health issues globally[2].

Maize is a very nutrient-demanding crop, requiring the intensive application of inorganic or organic fertilizers to produce a high yield[4]. Fertilizers are needed to replenish the nutrients that are detached from the soil when plants are collected and to supplement the soil with more nutrients to increase production[5]. However, the continuous application of chemical fertilizers may cause a nutrient inequality and reduce the uptake of additional primary nutrients, limiting the growth of this crop. Furthermore, the incessant addition of chemical fertilizers can also affect the soil and plants negatively because most farmers in developing countries apply them without first testing the soil, resulting in the incorrect amounts and types being used.

Intensive cropping systems demand high amounts of fertilizer application to the soils, which conserved through good plant nutrient management systems[6]. Intense agriculture also had harmful properties on the soil medium in latest years (e.g., degradation of the soil organic matter, soil erosion and water impurity)[7], which can also reduce yield. Therefore, sustaining and improving soil are critical for maintaining cropping productivity for future generations[8] and management methods that reduce the demand for agricultural chemicals are needed to avoid adverse environmental effects[9].

Application of inorganic fertilizers alone has not proven beneficial in intensive agriculture because it aggravates soil degradation[10]. However, the combined application of both organic and inorganic dressings by farmers has been stated to increase yield and conserve soil productivity. For example, poultry manure, cow manure and household wastes have been revealed to increase the efficacy of mineral that are not existing in chemical fertilizers[11]. Furthermore, supplementation with organic manures to reverse the current trend of physical, chemical and biological degradation of the soil has been recommended.

The use of dung and mulching are two of the basic cultivation techniques in organic agriculture[12]. Numerous revisions have exposed that the use of various organic compounds such as cattle manure, poultry dung and farmyard manure as soil amendments is favorable for increasing crop productivity, particularly among existing farmers in West Africa[13]. Organic manure benefits the soil in many ways, such as improving the soil culture, aeration and enhancing the microorganisms in the soil that make plant nutrients available. However, although several studies have shown that adding organic fertilizer such as dung can improve the biological characteristics of the soil, in addition to crop nutrition, production and quality, the reusing of organic manures should be applied with care to decrease the accumulation of toxic substances and contamination of the environment[14,15]. Therefore, the goal of this field experiment was to assess the role of 5 different doses of cattle manure on maize yield.

MATERIALS AND METHODS

Experimental site: The experiment was conducted at the National Center for Agricultural Research and Extension in the Jordan Valley, northwest of Amman, Jordan, during summer 2015.

Soil and fertilizer analysis: The soil and cattle manure were analyzed at the National Center for Agricultural Research and Extension, Amman, Jordan before planting. The pH of the soil was 7.7, EC (ds m^{-1}) was 1.32 and N (%), P(ppm), K(ppm) was 0.07, 18.5 and 420, respectively. While the EC (ds m^{-1}) for organic manure was less than 1 and N(%), P(%), K(%) was 1.8, 1.3, 1.5, respectively.

Table 1: Effect of organic manure treatments on maize morphological characters

Treatments	PH (cm)*	SD (cm)*	EL (cm)*	ED(cm)*	PN ha^{-1}*	EN ha^{-1}*
T1	168.75^{d}	2.4^{b}	16.18^{c}	3.8^{b}	52917^{a}	37500^{c}
T2	178.25^{c}	2.5^{b}	16.15^{c}	3.9^{b}	59584^{a}	41250^{c}
T3	184.50^{bc}	2.5^{b}	16. 83^{bc}	3.9^{b}	61667^{a}	47917^{b}
T4	190.25^{b}	2.6^{b}	16.73^{bc}	3.9^{b}	64583^{bc}	53333^{b}
T5	203.00^{a}	2.7^{a}	17.53^{ab}	4.0^{ab}	65417^{c}	60000^{a}
T6	210.00^{a}	2.8^{a}	18.15^{a}	4.2^{a}	65834^{d}	63750^{a}

Means within column followed by the same letters are not significant at LSD 5%, *pH: Plant height, SD: Stem diameter, EL: Ear length, ED: Ear diameter, PNh^{-1}: Plant number/hectare, EN h^{-1}: Ear number/hectare

Treatments, experimental design and plot size: Six soil treatments were used: No cattle manure (T1, control), 4 t ha^{-1} cattle manure (T2), 8 t ha^{-1} cattle manure (T3), 12 t ha^{-1} cattle manure (T4), 16 t ha^{-1} cattle manure (T5) and 20 t ha^{-1} cattle manure (T6). Treatment combinations were organized in a randomized complete block design (RCBD) with 4 replications. Each plot was 6 m^2 (3 m$\times$2 m), giving a total cultivated area of 144 m^2 (6 treatments$\times$4 replicates$\times$6 m^2 plots). Plants were grown at a spacing of 0.2 m within rows and 0.7 m between rows. The planting and harvesting dates were April, 16 and July, 14, 2015, respectively (Table 1).

Soil preparation, fertilizer application and planting: Before sowing, the seed bed was prepared by plowing and disking the soil. The manure was then mixed with soil before planting.

Measurements and data gathering: Mature ears were harvested by hand picking and 10 plants/plot were randomly tagged for the determination of plant height (cm), stem diameter (cm), ear diameter (cm), ear length (cm), plant number, ear number, total green yield (t ha^{-1}), green seed weight (t ha^{-1}), green straw weight (t ha^{-1}), seed dry weight (t ha^{-1}), straw dry weight (t ha^{-1}), total dry weight (t ha^{-1}) and harvest index (%).

Statistical analysis: The data were analyzed using SAS package version 9 and means were compared using the least significant difference test at a level of confidence of $p<0.05$[16].

RESULTS AND DISCUSSION

Plant height: Manure had a significant result on plant height, with the highest application (T6, 20 t ha^{-1}) giving the greatest plant height (210 cm) followed by T5 (16 t ha^{-1}, 203 cm), while the control (T1, no cattle manure) resulted in the lowest plant height (168.75 cm) (Table 2).

Stem and ear diameters: The highest diameter of stem (2.8 cm) was gained with the T6 treatment (20 t ha^{-1} cattle manure) followed by T5 (16 t ha^{-1}), while T1 (no cattle manure) gave the lowest diameter (2.4 cm). Cattle manure (T6 treatment) significantly increased $p<0.05$ ear diameter compared with the control (T1), resulting in 11% increases (Table 1).

Ear length: Ear length were affected with manure significantly, with the maximum ear length (18.15 cm) being recorded for T6, followed by T5 (17.53 cm) and T2 (16.15 cm) (Table 1).

Plant and ear numbers: Number of plants gained in T5 and T6 were significantly higher ($p<0.05$) than the other treatments with the highest value being recorded for T5 (65,834 ha^{-1}) followed by T6 (65,417 ha^{-1}) and the lowest number being recorded for T1 (52,917 ha^{-1}). Similarly, number of ears also differed significantly with different doses of manure, with T6 giving the highest number (63,750 ha^{-1}) followed by T5 (60,000 ha^{-1}) and T1 giving the lowest number (37,500 ha^{-1}) (Table 1).

Yield and yield components: Cattle manure affect seed dry weight, straw dry weight and total dry weight significantly, with T6 resulting in the greatest levels of each (seed, 8.38 t ha^{-1}, straw, 19.98 t ha^{-1} and total, 20.15 t ha^{-1}) followed by T5 (seed, 7.60 t ha^{-1}, straw, 20.03 t ha^{-1} and total, 27.58 t ha^{-1}, while T1 gave the lowest values (seed, 5.40 t ha^{-1}, straw, 14.75 t ha^{-1} and total, 20.15 t ha^{-1}) (Table 2).

Harvest index: Harvest index (HI) is the ratio seed weight to biological yield (total yield) represented as a percentage. The maximum HI (29.5%) was recorded for T6 followed by T3 (29.25%) and the minimum HI (27.0%) was recorded for T1 (Table 2) but the differences between treatment were not significantly different.

Plant height and stem diameter: Plant height and stem diameter are important growth characteristics that affect the productivity of maize. Both traits significantly $p<0.05$

Table 2: Effect of organic manure treatments on maize yield and yield components

Treatment	TGW (t ha^{-1})	GSW (t ha^{-1})	*GSW (t ha^{-1})	SeW (t ha^{-1})	SDW (t ha^{-1})	TDW (t ha^{-1})	HI
T1	38.28^{f}	10.28^{e}	28.03^{d}	5.40^{d}	14.75^{c}	20.15^{d}	26.85^{a}
T2	41.93^{e}	11.55^{de}	30.38^{cd}	6.10^{d}	15.98^{bc}	22.15^{c}	27.55^{a}
T3	45.00^{d}	13.05^{cd}	31.95^{c}	6.53^{c}	16.08^{bc}	22.53^{c}	29.00^{a}
T4	49. 58^{c}	13.83^{c}	35.75^{b}	6.73^{bc}	17.45^{b}	24.20^{b}	27.89^{a}
T5	56.80^{b}	15.65^{b}	41.18^{a}	7.60^{ab}	20.03^{a}	27.58^{a}	27.55^{a}
T6	60.38^{a}	17.83^{a}	42.58^{a}	8.38^{a}	19.98^{a}	28.35^{a}	29.53^{a}

Means within column followed by the same letters are not significant at LSD 5%, TGW: Total green weight, GSW: Green seed weight, *GSW: Green straw weight, SeW: Seed dry weight, SDW: Straw dry weight, TDW: Total dry weight, HI: Harvest index

increased with increasing doses of manure up to 20 t ha^{-1}, supporting the results of previous studies. For example, the use of poultry manure at dose of 20 t ha^{-1} increased plant and stem diameter[17], while farmyard manure considerably increased the plant height, stem diameter and green yield of maize in Pakistan[18]. Furthermore, a significant increase in dry matter accumulation in maize following a substantial increase in the rate of organic manure[19]. It was found that maize plants that were treated with poultry dung were taller than those that were left unfertilized[20].

Stem diameter is a particularly important characteristic for the plants when it is being grown for feed because the amount of maize feed produced is mainly a function of stem thickness[21] which was increased with application of organic dung to the soil[22].

Ear length and diameter: Ear length and diameter were significantly increased with increasing the rates of cattle manure, confirming the results of other researchers for organic manure[23], granular bio-fertilizers[24] and poultry manure[17].

Ear number: Number of ears is a good indicator of yield. It was indicated that number of ears to be increased with increasing the doses of manure upto 20 t ha^{-1}. This finding agrees with the results of other studies, who found that poultry manure results in a higher ear number than chemical fertilizers or no fertilizers[25] and poultry manure gave a higher yield than no fertilizer[17].

Yield and yield components

Seed dry weight: Seed yield is essential parameter for maize output. It was found that the seed dry weight was higher when manure was added to the soil compared with the control. Other studies have found similar trends for poultry and farmyard manures[26] organic manure[27] and poultry manure[28,29] with the latter also being found to be more effective than the use of chemical fertilizers.

Straw dry weight: Straw is a good feed for animals. It was found that higher doses of manure resulted in higher straw dry weights, matching the results of previous studies. For example, organic fertilizers gave a higher straw weight than the control treatment[30] and both cattle and chicken droppings led to a significant effect in the green and dry straw weight of maize positively compared with chemical fertilizers or no fertilizers[22].

Total dry weight: Total dry weight was increased with increasing doses of organic manure upto 20 t ha^{-1}. This finding matches that of other researchers for farmyard manure[21] poultry, farmyard manures[26] and poultry manure[29], with the latter gave a positive effect than chemical fertilizers. The observed effects of manure on the maize plants were likely owing to its constituents, as shown in other studies. The better performance in plant growth and yield constituents that was associated with manure could be attributed to the essential nutrient elements it contained[31], which increased the photosynthetic efficiency. In addition, organic matter improves the physical conditions of the soil by improving soil structure, increasing the water holding capacity, modulating soil structure and soil aeration and adjusting the soil temperature.

Organic manure also positively affects the nutrients. The addition of organic sources can increase the availability of macro- and micronutrients, which are protoplasmic constituents and accelerate cell division and cell elongation, which, in turn, increases various growth characteristics[32]. Indeed, organic manure represents a good fertilizer material not only attributable to its high N, P and K contents, but because it is more readily available than chemical fertilizers and has a more steady impact on the soil, slowly releasing nutrients to crops and improving the physical and chemical properties of the soil[33].

Harvest index: No significant difference in HI between treatments, but increasing the rate of manure did increase HI to some extent. The addition of poultry and farmyard manures increased HI[26]. It was found that the organic manure increased seed yield and HI, confirming the results of the present study[34].

CONCLUSION

The results of this study indicate that the use of 20 t ha^{-1} cattle manure to the soil in this region can result in an increased maize grain yield, straw yield and total dry yield. Therefore, it is recommended that cattle manure becomes the preferred option as a fertilizer in Jordan as a result of its marked effect on the yield and yield components of maize, in addition to its lower price than chemical fertilizers and its availability throughout the year.

SIGNIFICANCE STATEMENTS

This study discovers the importance of cattle manure as a source of soil amendment and crop nutrients that can be beneficial for maize plants by increasing their productivity. The use of cattle manure as a source of nutrients in agricultural production decreases environmental pollution and leads to economic savings for farmers.

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