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Effect of Liquid Cattle Manure on Yield and Yield Components of Corn (Zea Mays L.), and Soil Property

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Abstract

Liquid Cattle manure (LCM) has long been recognized to be very important organic fertilizer. This paper reports the effectiveness of different levels of LCM on the yield of maize (Zea mays L.), and soil properties. The study was carried out at Luannan Science and Technology Backyard (LSTB), Hebei province, China in the year 2020. The experiment was conducted in pot and has seven treatments with 10 replications: CK(without any fertilizer), CF(5.3gN,1.7gP and 1.82gK pot^{-1}), T1(5.12gN, 0.21gP, 26.8gK and 20gNa pot^{-1}), T2(2.56gN pot-1, 0.1gP, 13.4gK and 10gNa pot^{-1}), T3(1.7g pot^{-1}, 0.07gP, 8.9gK and 6.7g Na pot^{-1}), T4(1.25g pot^{-1}, 0.05gP, 6.56gK and 5.07gNa pot^{-1}) and T5(1.02gN, 0.042gP, 5.36gK and 4.02g Na pot^{-1}). Soil samples were analyzed for soil pH, SOM, TN, available phosphorus and available Potassium content. All soil parameters significantly increased except soil pH. Number of kernels, number of rows ear^{-1}, and number of kernels row^{-1}, weight of 100 kernels, stover, and kernel yield were significantly affected by application of LCM. CF scored maximum values for all these parameters followed by T1. The highest rate of LCM application (13.5L pot^{-1}) improved maize yield by 53.7% and the lowest rate (2.7L pot^{-1}) improved maize yield by 37% over the control. The treatments generally showed significantly higher nutrient uptake than CK.

Keywords: Application; Liquid cattle manure; Maize (Zea mays L.); Growth; Yield

Introduction

Maize is a multi-purpose crop that has high nutritive importance as it comprises near 72% carbohydrates, 10% protein, and other nutrients [1]. Maize is typically used for food, feed, fodder, and in industries to produce various biofuel and medicines [2]. Inorganic fertilizer is the greatest plant nutrient source that provides essential nutrients for plant growth and increases maize yield worldwide. The maize production is enhanced with N rate or chemical fertilizer used. The recent agricultural method has greatly dependent on mineral fertilizer applications that have adversely impact on soil property, ecosystem, and crop yield. Increasing plant production on a justifiable basis is an interesting concern in the current farming system [3]. Several nutrients are fixed in the soil or leached down by water during chemical fertilizer application since plants cannot uptake all the nutrients applied. An excessive chemical fertilizer application causes health problem, soil degradation, soil structure deterioration, and environmental pollution mostly in water bodies [4].

China is a foremost maize-producing country worldwide, for nourishment and animal feed by utilizing overabundance chemical fertilizers. Over utilization of nitrogen fertilizer and incorrect application stage strategies have become common in the pursuit of high yield. The yield of crops is normally determined by the quality and the amount of fertilizers applied. So, in China to upgrade the soil fertility and yield, chemical fertilizers are regularly utilized. Overuses of chemical fertilizer have been linked with environmental pollution, change in soil texture, and physical property. Moreover, the nutritive value of the crops will be influenced by the persistent utilize of chemical fertilizers, and chemical fertilizers will broaden the expense of crop production [5]. Even though inorganic fertilizer improves crops yield in the brief term, it declines soil organic carbon, causes soil acidification, and plant nutrient loss. To clarify this problem organic fertilizer application is a broadly accepted tactic to continue SOC stock [6].

Liquid cattle manure (LCM) is one of the organic fertilizers and it is a blend of cattle urine, dung, dairy washing water, rainwater, and waste food. It contains less than 15 % of dry matter, which presents in the form of dissolved organic matter. LCM is a critical resource, being reused and mixed into the soil for crop production [7].

LCM improves soil fertility concerning macro-nutrients, particularly nitrogen. The amount of obtainable nitrogen in LCM, which is mostly in NH_4^+-N form, is less compared to chemical fertilizer. In the other hand, liquid manure comprises a high amount of directly obtainable nitrogen, because of its urine content. Application of liquid manure to the soil can improve crop development and it enhances plant produce [8].

Inappropriate management of manure can cause environmental contamination. LCM is a reasonably ecologically unfavorable nitrogen nutrient basis if not recycled in a proper N loss controlling method. The creation and utilization of huge volumes of manure can contaminate the environment and N sensitive ecosystems reserves such as groundwater and surface water. It pollutes these ecosystems in different ways in the form of ammonia volatilization and nitrate leaching [9]. At present many different technologies are available for manure treatment, some of these technologies are utilized to move forward manure management and application, some to concentrate nutrients, and others to generate energy [10].

Soil productivity is a dynamic problem in reducing plant production

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and poor soil productivity has a great role in maize yield reduction. The use of fertilizers from animal source is supportive to the soil nutrient balance and facilitates environmental protection. Manure application represents a great strategy of keeping up crop yield and organic carbon supplies. Therefore, manure is used as a plant nutrient and it improves soil productivity.

The production of mineral fertilizers expends a huge quantity of energy besides cash and also creates polluting effects in the environment. For this reason, using organic fertilizer alongside or exclusive of mineral fertilizers is the finest probable result heading for these complications. In maize cropland, using organic manures as an alternative method to reduce environmental pollution threats is very important. The current analysis has been planned to assess the influence of LCM on maize crop production and soil properties in Luannan county, Hebei province, China.

Materials and Methods

The study region

A pot trial was done at North-East China, Hebei Province, Luannan County on 35m 2 areas of land in Luannan Science and Technology Backyard (LSTB) compound, during the crop growing year of 2020. The pots were arranged outside where it can acquire precipitation and sun light properly. The region was characterized by erratic, low, and unpredictable seasonal rainfall. The annual rainfall varies from 400 to 1000mm, and the average annual rainfall is 658mm. The average temperature was 10.6°C. As a result, moisture deficit is the most pressing problem, but it was supported by irrigation. The soil in this area was sandy type. Farmers in the study region were mainly produced cereal crops like winter wheat, rice, and maize, by using the main season rainfall and irrigation. Irrigation is applied based on the crop water requirement. The summer maize was planted in late June and harvested in early October.

Experimental materials

Deng hai 605 maize varieties were used for the trial. The dimensions of a pot are 37cm (diameter) × 60cm (height). It takes 108 days to harvest, and with yield potential under the research of 14 t ha^{-1}. The fertilizer material used was liquid cattle manure and chemical fertilizer as one treatment (farmer practice). Both chemical fertilizer and Liquid Cattle Manure (LCM) were obtained from Fengtianbao fertilizer company, a large-scale standardized fertilizer company, supply fertilizer and LCM to Luannan STB. The LCM was produced by mixing animal urine, dung, and beddings, then after the solid part settle down the liquid part was fetched and used as organic fertilizer.

The soil was collected from 25m^2 of arable land after cleaning weeds and the soil samples were taken before pot filling from 9 spots in Zigzag method from the collected soil by an auger and were mixed. 200g of composite soil sample was taken by a plastic bag and send to Quzhou soil laboratory. Soil samples were taken after harvesting from all the experimental pots with a 10cm interval: 0-10cm, 10-20cm, 20-30cm depth of each pot from the top to bottom by using the trowel, and knife. The soil sample was dried at room temperature and crushed to pass through a 2mm sieve and prepared for laboratory analysis. The indicators to be tested were: pH, SOM, TN, available phosphorus, and available potassium by following the standard analytical procedures. The sample of Liquid cattle manure (LCM) is also taken from each container, mixed and sends to the laboratory to test its nutrient contents: TN, available N, total P, total K and Na.

The trial has seven treatments that repeat 10 times, and a pot design was used. Totally the trial has 70 pots. In this section the LCM treatments were compared with Farmer practice, and the control, to test the effect of LCM on maize yield and also different rates of LCM were used to clarify the right amount that gives better grain yield. The treatments were:

CK = control or treatment without any fertilizer,

Chemical fertilizer (CF) used was 353.3kg N, 113.3kg P, 121.3kg K ha^{-1},

T1 = Liquid cattle manure used was 400kg N, 16.3kg P, 2090.4Kg K, and 1567.8kg Na ha^{-1},

T2 = Liquid cattle manure used was 200kg N, 8.15Kg P, 1045.2Kg K, and 783.9kg Na ha^{-1}.

T3 = Liquid cattle manure used was 132.6kg N, 5.46Kg P, 694.2Kg K, and 522.6kg Na ha^{-1}.

T4= Liquid cattle manure used was 97.5kg N, 3.9Kg P, 511.6Kg K, and 395.4kg Na ha^{-1}.

T5= Liquid cattle manure used was 79.5kg N, 3.12Kg P, 413.4Kg K, and 312kg Na ha^{-1}.

Note: from the TN content of LCM, 67% was in available form.

All liquid cattle manure used was diluted with water in (1:2) ratio i.e., one liter of LCM was diluted in two liters of water.

The details of the fertilizer treatment were given in table 1. The distance of pot, within and between different treatments were 50cm and 1m respectively that was to prevent fertilizer and LCM from crossing the boundaries of pots. Liquid Cattle Manure (LCM) was collected into a jerry can to decide the amount and applied by hand to every plant after diluted with water. Pot management like irrigation and manure application was performed properly.

Table 1: The detail of treatments.

Treatments	NPK and Na plant^{-1} (g) respectively	Diluted LCM plant^{-1} (L)	Available N in LCM (g)	CF used Urea, DAP and KCl	Application time	Applied amount
CK	/	/	/	/	/	
CF	5.3g N,1.7g P, 1.82g K	/	/	115g, 37g and 30g respectively	2times, at sowing and at v6	All PK and 30% N, at sowing 70%N at v6
T1	5.12N, 0.21P, 26.8K, 20.1Na	40.5	3.43	/	3times, at sowing, v12 and R1	13.5L at each time.
T2	2.56N, 0.1P, 13.4K, 10Na	20.25	1.7	/		6.75L
T3	1.7N, 0.07P, 8.9K, 6.7Na	13.5	1.1	/		4.5L
T4	1.25N, 0.05P, 6.56K, 5.07Na	10.2	0.83	/		3.4L
T5	1.02N, 0.04P, 5.3K, 4Na	8.1	0.68	/		2.7L

Manure was applied at sowing time on 27th June, on 16th August, and on 15th September 2020, and the maize was harvested on 13th October 2020. The quantity of LCM used for each treatment was indicated in table 1. Farmer practice treatment or chemical fertilizer (CF) which was used by the local farmers for maize consisted of Urea, DAP, and Kcl at 1.59g N plant^{-1}, 1.7g P plant^{-1}, 1.82g K plant^{-1}, as base fertilizer, and urea at 3.7g N Plant^{-1} as topdressing.

The total application rate of LCM on maize for T1, T2, T3, T4, and T5 was 13.5, 6.75, 4.5, 3.4, and 2.7-liter plant^{-1}, respectively. LCM for all LCM treatments utilized in a proportion of 1:1:1 at sowing, v12, and R1.

The pot was prepared manually before sowing, arranged according to treatments, and leveled. Three seeds per pot were planted at about 5cm depth to ensure adequate emergence and then, uproot the additional seedling 10 DAE to one plant per pot to reduce competition. The LCM was applied at sowing, v12, and R1 stage whereas chemical fertilizer was sown at the base. For CF (farmer practices) treatment, 30% of the N was sown as base while 70% of N was sown as top-dressing after thirty-five days from sowing date. All the recommended management was the same for all treatments. Harvesting was done after maize matured when the foliage and ears of the crop turned brown. It was threshed manually.

Crop growth parameters and measurements

Number of leaves

The number of leaves of all plants from each treatment was counted at 30, 50, 70 and 90 days after sowing.

Leaves chlorophyll

It was recorded from all plants of each treatment at 30, 50, 70 and 90 days after sowing within 20 days intervals by measuring the content of chlorophyll in plants. It was recorded from all plants of each treatment by measuring the number of leaf chlorophyll at similar stage by SPAD meter.

Plant height

It was recorded from all plants at 30, 50, 70 and 90 days after sowing within 20 days intervals by measuring their height from base to the collar leaves during the vegetative stage and to the tip of the stem at harvest.

Stem diameter

It was measured from all plants at 30, 50, 70 and 90 days after sowing within 20 days intervals by using a caliper.

Ear number plant^{-1}: the total number of ears in all plants from every treatment was counted to get the number of ears plant^{-1}.

The number of kernels ear^{-1}

At harvest, kernels of one ear from all plants in treatment were calculated and their mean number was calculated as the kernel number ear^{-1}.

Hundred kernel weight

It was the weight of 100 randomly selected kernels taking from the total harvest, from every treatment and the weight was fine-tuned to 14% moisture level after measuring the moisture content of the grain with a seed moisture tester.

Ear length

The length of each ear per plant was measured after harvest by using a ruler and recorded.

Ear diameter

All plant's ears were taken from each plant and the diameter was measured at the center of the ear by a Vernier caliper ruler.

Number of rows ear^{-1}

The number of rows ear^{-1} of each plant was counted and their mean number was calculated as number of rows ear^{-1}.

Stover yield (g plant^{-1})

The Stover was measured after harvest. All plants were measured after harvest for this indicator. The fresh plants on the pot were cut down and put into the craft paper bags then put into the oven-dry at a constant temperature of 105^{o}c for thirty minutes, and then dried to a constant weight at 80°c.

Kernel yield (g plant^{-1})

It was measured after separating the kernels from the harvested ears from each plant by using a sensitive balance. The kernel yield was cleaned, weighed and the yield was adjusted to 14% moisture level.

Agronomic efficiency

Nitrogen uptake

The nitrogen uptake was calculated as the following formula indicated below:

Straw N uptake = SNCT (the straw N concentration) X DMSW (the dry matter of straw weights).

Grain N uptake = GNCT (the grains nitrogen concentration) X GW (the weight of the grains).

Phosphorus uptake: Similar equation of nitrogen uptake was used to evaluate the phosphorus uptake.

Potassium uptake: Similar equation of nitrogen uptake was used to evaluate the potassium uptake.

Nitrogen use efficiency

It was obtained by dividing the difference of the N uptake by fertilized treatment and unfertilized control to the total applied nitrogen.

NUE = (N uptake fertilized–N uptake unfertilized)/N applied.

Regression analysis: It indicates the relationship between dependent and independent variable as it describes how dependent variable will change when one or more independent variables changes. Maize yield is dependent and N rate is independent variable. It was calculated by Microsoft excel.

Statistical data analysis

All the measured factors were subjected to analysis of variance (ANOVA) which was suitable to a trial in a pot according to the IBM SPSS statistics version 25. When the results of the treatments were found to be significant, the means were compared using the Duncan test at a 5% level of significance. When reporting the results of the statistical analyses, lower case letters indicate the level of significance at $P < 0.05$.

Test results

Soil physio- chemical properties of the study area.

The score of soil physio-chemical properties before sowing were listed below. The textural class of the soil in the production area was sandy type. The soil pH in water was 7.44 which were found in slightly alkaline soil, the SOM, SOC and TN of the experimental soil was 0.47%, 0.27% and 0.028%. The soil available P and available K was 7.26mg kg^{-1} of soil, and 48.5mg kg^{-1} of soil respectively. The soil organic carbon of the experiment trial was very low.

In this trial all the chemical properties of the soil after harvest were influenced by the treatments. There was a statistical difference between treatments in pH, TN, available phosphorus, available potassium, SOM, and SOC after harvest (fig. 1-6).

Description of LCM used in the trial

The LCM utilized in the trial was tested for TN, ammonium nitrogen, available P, available K, and Sodium. Table 2 indicates the scores of the liquid cattle manure contents.

Soil properties

Soil pH at different soil depth

The soil pH tested was collected from different soil depths with 10cm intervals 0-10cm, 10-20cm, and 20-30cm pot depth from top to bottom. The highest pH value was scored by CK at each soil depth and the lowest was scored by different treatments. T1 scored the lowest pH (6.32) at 0-10 cm soil depth and at soil depth 10-20cm and 20-30cm, T3 scored the lowest value (6.78 and 7.03). There were statistical differences observed between treatments and the control (Figure 1).

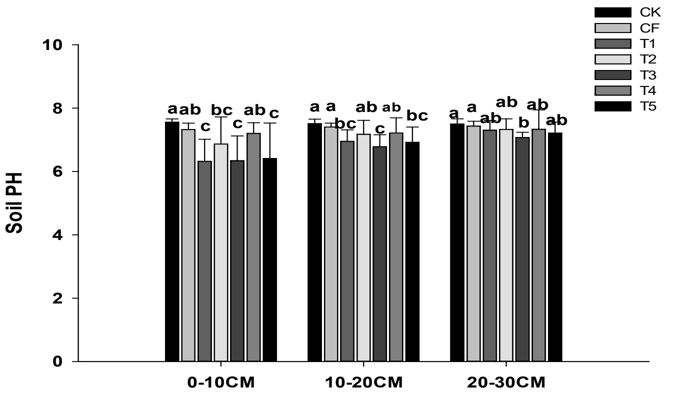

Figure 1: Effect of treatments on Soil pH at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

Content of soil total nitrogen, phosphorus, potassium, organic matter, and organic carbon at different soil depth

The soil TN content in all treatments was higher than the TN content of CK at both 0-10cm and 10-20cm soil depth. The TN content of CF, T1, T2 and T4 were significantly higher than CK at 0-10cm soil depth. The soil TN was non-significant to the control at 10-20cm soil depth. The TN content of treatments was higher than the control CK at 20-30cm soil depth except T3 and T5. The treatments and control were statistically similar at this soil depth. The soil TN was higher at the top of the soil than at the middle and bottom of the pot. The higher TN at 0-10cm soil depth was scored by CF, at 10-20cm by T2 and at 20-30cm by T1 treatments whereas the lowest were scored by CK at both 0-10cm and 10-20cm, and by T3 at 20-30cm soil depth (Figure 2).

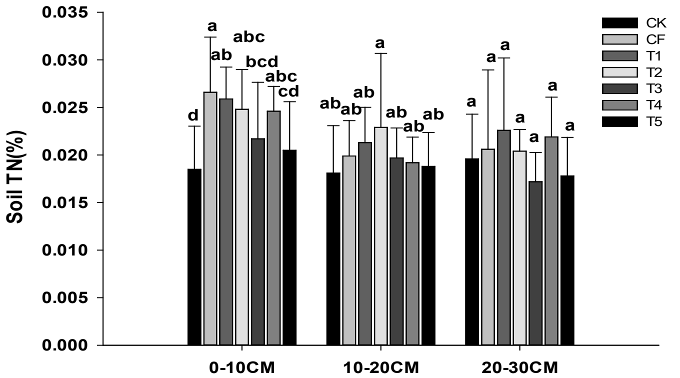

Figure 2: Effect of treatments on Soil Total Nitrogen at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

The soil phosphorus content of treatments was higher than the control treatment, except T5 at 0-10cm soil depth, and T1, T2, and T4 were significantly different from CK. The soil phosphorus content of all treatments was greater than the CK except T5. T2 was significantly higher than the control CK at 10-20cm soil depth. The soil phosphorus content of all liquid manure treatments was significantly different from CK except T5 which was produced by the lowest amount of liquid manure at 20-30cm soil depth. T4 scores higher P content at both 0-10cm and at 20-30cm, and T2 scored higher P content at 10-20cm the lowest was scored by T5.

Table 2: The nutrient content of Liquid cattle manure used in the study.

Indicator	Indicator Content (mg L^{-1})
Total Nitrogen	379.88±211.95
Ammonium Nitrogen	255.94±109.36
Available Phosphorus	15.76±5.92
Available Potassium	1988.83±298.20
Sodium	1492.1±595.53

Figure 3 Effect of treatments on Soil P at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

The soil Potassium content at 0-10cm soil depth of T1, T2, and T4 were significantly different from CK. T1 was significantly higher than CK at 10-20cm soil depth. The soil Potassium content of the T4 treatment was significantly different from CK and, T1 which was produced by the highest amount of liquid manure was greater than the control treatment at 20-30cm soil depth. T2, T1 and T4, scored higher K content at 0-10cm, 10-20cm, 20-30cm soil depth respectively and CF, T5 and T3 scores the lowest K content at 0-10cm, 10-20cm, 20-30cm soil depth respectively.

Figure 4 Effect of treatments on Soil K at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10.

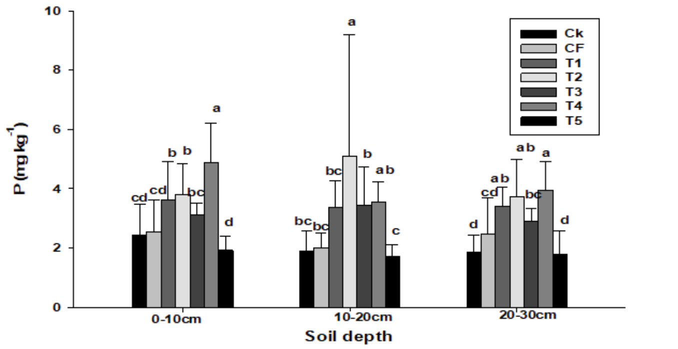

Figure 3: Effect of treatments on Soil P at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

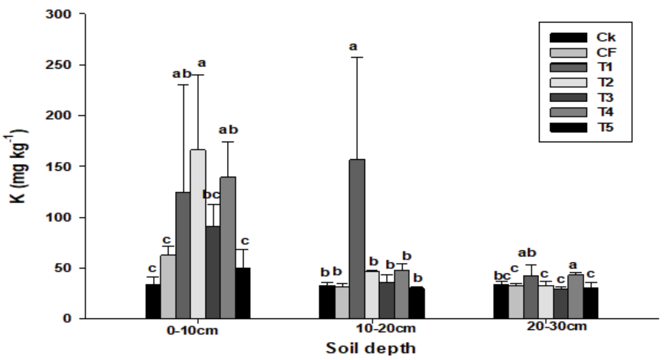

Figure 4: Effect of treatments on Soil K at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

The values followed by the different letters show statistically significant differences at P<0.05.

The SOM content of all LCM treatments were greater than SOM content of CK at 0-10cm soil depth, and the SOM content of T2 was significantly greater than SOM of CK at 10-20cm soil depth, and the SOM of all treatments were higher than Control (CK) at this soil depth. The SOM of T4 was significant to CK at 20-30cm soil depth. T1, T2, and T4 scored higher SOM content at 0-10cm, 10-20cm, 20-30cm soil depth respectively, whereas CK scored the lowest SOM content at 0-10cm, 10-20cm and T3 scored lowest SOM at 20-30cm soil depth.

Figure 5 Effect of treatments on Soil OM at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

All the results of SOC were similar to SOM. Because it was calculated from SOM.

Figure 6 Effect of treatments on Soil OC at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10.

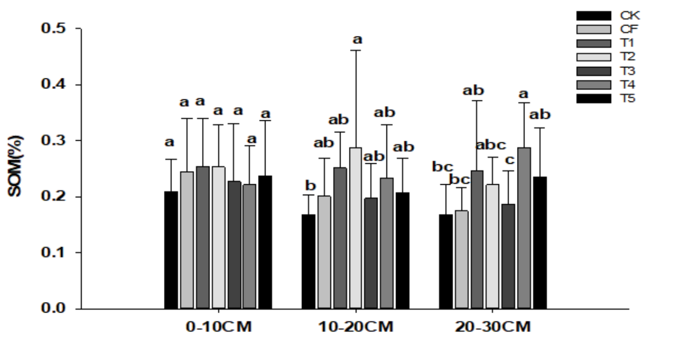

Figure 5: Effect of treatments on Soil OM at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

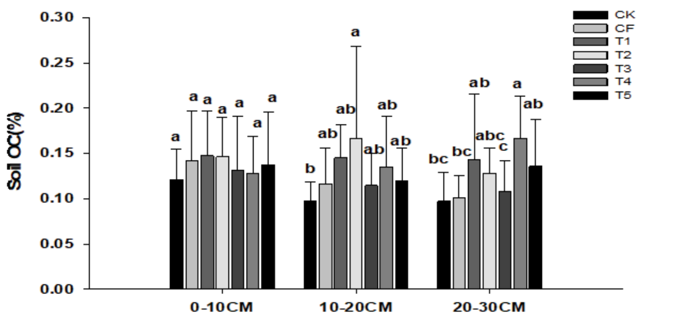

Figure 6: Effect of treatments on Soil OC at different soil depth. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

The values followed by the different letters show statistically significant differences at P<0.05.

Crop growth parameters and measurements

Number of leaves

The maize leaf number was 7-9, 9-11, 13-15, 15-17 at 30, 50, 70, and 90 days after sowing (DAS) respectively. There was a significant difference among six treatments (one chemical fertilizer, five liquid manure treatments) and control or without using any fertilizer. CF and T2 were a statistically different from CK after 50 and 90 days from sowing. CF scores higher leave numbers and CK scores lowest except at 30 DAS (Table 3).

Plant height

The maize plant height scores at, 30, 50, 70 and 90 days after sowing (DAS) were 41.6-55.1cm, 84.6-100.5cm, 134.4-162.1cm and 192.1-218cm, respectively. The influence of various treatments on plant height was observed at all plant growth stages from 30 to 90 days from the sowing date. Chemical fertilizer treatment (CF) and T2 were scores higher plant height and T5 scores lowest plant height after 30 days from sowing, CF was a statistical different from all treatments after 50 and 70 days from sowing. There was a statistical difference between treatments and the Control (Table 4).

Table 3: Maize leaf number at different days after sowing.

Treatments	30 DAS	50 DAS	70 DAS	90 DAS
CK	8.2±0.4ab	9.7±0.6c	13.6±0.8c	15.6±0.7c
CF	8.8±0.7a	11.1±0.8a	14.6±0.7a	16.8±0.6a
T1	8.0±0.6b	10.0±0.6bc	14.3±0.6abc	16.2±1.0abc
T2	8.4±0.5ab	10.6±0.9ab	14.3±0.6abc	16.7±0.6a
T3	8.2±0.6ab	9.8±1.2bc	13.8±0.8bc	16.6±0.7ab
T4	7.8±0.8b	9.7±0.8c	13.8±0.8bc	15.9±0.7bc
T5	8.2±0.4ab	10.3±0.6abc	14.4±0.7ab	16.2±0.6abc

CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at $P<0.05$.

Table 4: Plant height of maize at different days after sowing.

Treatments	30 DAS	50 DAS	70 DAS	90 DAS
CK	47.4±7.4ab	81.9±7.4d	140.6±6.9bc	198.1±9.1c
CF	54.2±11.5a	103.6±13.4a	162.1±14.5a	218.3±6.7a
T1	49.5±7.7ab	92.9±10.4bc	139.6±10.3bc	196.9±17.8c
T2	55.1±10.0a	100.5±18.3ab	148.7±9.5b	210.1±13.1ab
T3	47.7±6.0ab	91.5±9.0bcd	144.8±12.9bc	197.1±16.7c
T4	44.4±5.6b	81.5±5.0d	138.1±8.3c	202.3±7.8bc
T5	41.6±5.0b	84.6±5.6cd	134.4±9.9c	192.1±9.9c

CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at $P<0.05$.

Table 5: Stem diameter of maize at different days after sowing (DAS).

Treatments	30 DAS	50 DAS	70 DAS	90 DAS
CK	10.5±1.5b	19.1±1.5d	20.5±1.0c	20.8±1.3c
CF	14.6±3.4a	23.4±1.7a	23.7±1.9a	24.0±2.2a
T1	12.5±2.4ab	21.5±1.5abc	22.0±1.7bc	22.4±1.5abc
T2	14.3±3.9a	22.5±2.5ab	22.6±2.3ab	22.6±2.2ab
T3	11.7±1.7b	19.8±2.6cd	20.6±1.5c	20.8±1.2c
T4	11.0±1.9b	20.2±2.7cd	20.6±1.3c	20.9±1.5c
T5	10.1±1.1b	20.5±1.7bcd	20.7±1.1c	21.1±1.5bc

CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at $P<0.05$.

Stem diameter

The stem diameter of maize at 30, 50, 70, 90 days from sowing was 10.1-14.6cm, 19.1-23.4cm, 20.5-23.7cm and 20.8-24cm, respectively. There was a significant difference between treatments and also between treatments and control (Table 5).

Leaves chlorophyll

Leaves chlorophyll indirectly reflects the response of plants to nitrogen uptake and utilization. Maize leaves chlorophyll scores at, 30, 50, 70, and 90 days after sowing were 43.7-51.2mSPU, 45.8-53.1mSPU, 52.1-61.8mSPU and 42.5-49.4mSPU. There was a significant difference between treatments at, 30, 50, 70, and 90 DAS, and T2 scores higher and CK scores lower number of chlorophylls after 30 days from sowing. CF was a statistical difference from all treatments and scores the higher number of chlorophylls after 50, 70, and 90 days from sowing date (Table 6).

Effect of LCM on yield and yield components

Ear length and ear diameter

There was a statistical difference between Chemical fertilizer treatment (CF) and the control CK, in ear length, and the manure treatments and CK was statistically similar. CF, T1, and T2 were significantly different from T4 in ear diameter (Table 7).

Number of rows and kernel number

The number of rows ear^{-1} of each treatment and the control was statistically the same. The Kernel number per row and kernel number ear^{-1} of treatments were statistically different from the control (Table 8).

Ear weight and 100-kernel weight

All treatments were significantly different from CK, a treatment without any fertilizer in both ear weight and 100-kernel weight. This is because of using LCM for treatments T1 to T5 and chemical fertilizer application for farmer practice (CF). This indicates that the ear weight and 100-kernel weight was influenced by use of manure or fertilizer treatments.

Stover (g plant^{-1})

The Stover yield of treatments at harvesting time ranges from 103.5-136.7g plant^{-1}. The Stover of CF and T2 at harvesting time was significantly different from T3, T4, T5, and CK. The highest Stover yield was scored by CF while the lowest was scored by CK.

Figure 7 Effect of treatments on maize stoves yield. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at $P<0.05$.

Table 6: The Leaves chlorophyll of maize at different days after sowing.

Treatments	30 DAS	50 DAS	70 DAS	90 DAS
CK	43.7±5.6c	48.9±3.4abc	55.1±4.4b	42.5±5.3c
CF	45.7±6.8bc	53.0±5.7a	61.8±5.5a	53.8±4.8a
T1	49.7±2.5ab	50.9±4.4ab	52.1±3.3b	49.4±7.2ab
T2	51.2±7.8a	53.1±3.6a	53.76±3.5b	44.3±5.3bc
T3	49.2±3.8ab	51.7±2.8ab	54.3±4.7b	47.2±6.3bc
T4	47.4±4.0abc	45.8±5.2c	54.0±4.2b	47.2±4.5bc
T5	47.9±3.4abc	48.4±5.7bc	52.1±7.6b	45.8±4.9bc

CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

Table 7: Maize ear length and ear diameter.

Treatments	Mean ear length (cm)	Ear diameter (cm)
CK	17.1±0 .9b	14.3±0.4ab
CF	19.5± 1.0a	14.8±0.5a
T1	18.7± 0.9ab	14.8±0.4a
T2	18.4± 3.7ab	14.7±0.6a
T3	18.6±0.6ab	14.5±0.4ab
T4	18.3±1.6ab	14.1±0.3b
T5	18.5±1.5ab	14.4±0.6ab

CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

Table 8: The effect of LCM on maize yield components.

Treatments	Number of rows per ear	Kernel number per row	Kernel number per ear	100-kernel weight(g)
CK	15.6±1.2a	24.4±2.8c	379.2±42.3b	21.1±2.1b
CF	15.8±0.6a	34.7±2.4a	548.2±44.2a	26.0±2.6a
T1	16.4±1.2a	32.7±4.2ab	535.0±69.8a	24.8±2.1a
T2	16.6±0.9a	30.9±5.3b	513.4±94.9a	25.8±2.1a
T3	15.6±1.5a	34.1±2.0ab	530.4±46.8a	22.6±2.9b
T4	15.8±0.6a	33.3±2.4ab	526.8±50.4a	22.0±1.0b
T5	15.6±1.2a	32.1±3.6ab	502.0±79.2a	22.3±2.5b

CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

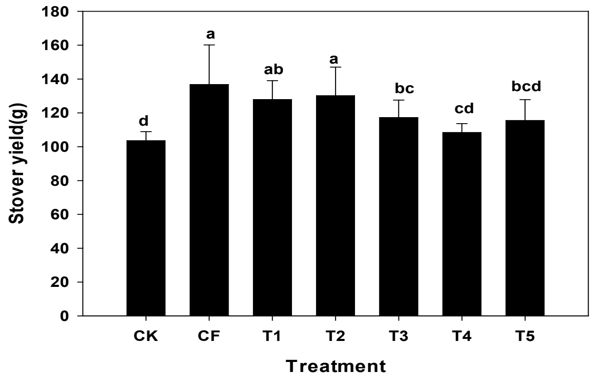

Figure 7: Effect of treatments on maize stoves yield. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

Kernel yield (g plant^{-1})

The kernel yield of treatments at harvesting time ranges from 86.4-145.8g plant^{-1}. The kernel yield of treatments after harvest of all treatments were statistically different from CK. CF was significantly different from T4 and T5. The manure treatments were statistically the same. Treatments: CF, T1(treatment with 5.12g N plant^{-1} from liquid manure, and T2 (2.56g N plant^{-1} from liquid manure application produced 145.8g plant^{-1}, 132.9g plant^{-1}, and 131.3g plant^{-1} of maize grain respectively. The control (CK) treatment gave a minimum yield (86.4g plant^{-1}). All treatments (CF, T1, T2, T3, T4 and T5) scored 68.6%, 53.8%, 51.8%, 47%, 39.5% and 37% higher kernel yield than CK respectively.

Figure 8 Effect of treatments on maize kernel yield. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

Regression analyses

The regression analyses of this experiment were non-significant. However, the yield of maize increases with nitrogen rate from LCM. It increases first and then flat as N rate increases (Figure 9).

Maize total NPK (Nitrogen, Phosphorus, and Potassium) uptake

The total N uptake in all treatments was statistically greater than CK. There was also a significant difference between treatments. CF was statistically different from all treatments, and T1 was significantly different from T3, T4, and T5, which was produced by a lower amount

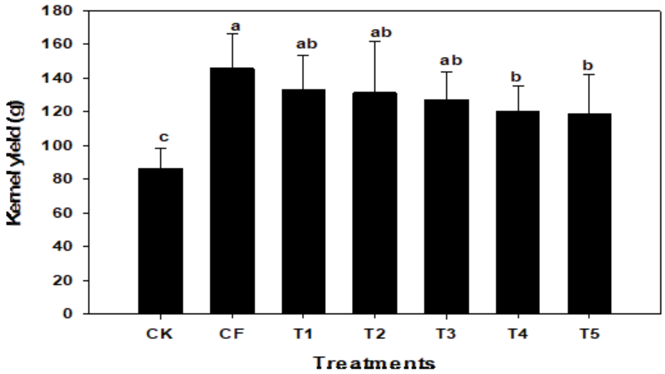

Figure 8: Effect of treatments on maize kernel yield. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment.

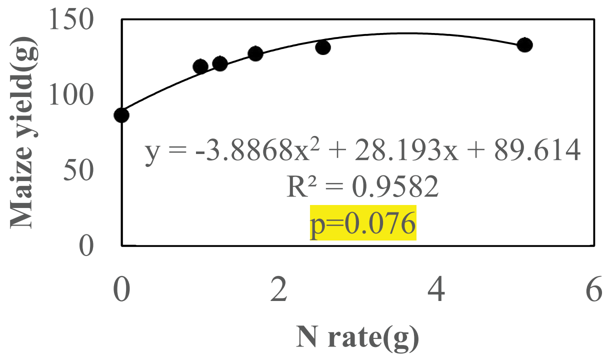

Figure 9: Relationship of N rate and maize kernel yield.

Table 9: Maize total NPK uptake of different treatments.

Treatment	TN uptake (g plant^{-1})	Total P uptake (g plant^{-1})	Total K uptake (g plant^{-1})
CK	2.02±.20e	0.40±.03de	0.67±.08c
CF	5.45±.55a	0.65±.11a	0.93±.12a
T1	4.07±.64b	0.51±.12bc	0.90±.08a
T2	3.82±.44bc	0.59±.14ab	0.88±.07a
T3	3.61±.50cd	0.43±.06cde	0.76±.07b
T4	3.43±.52cd	0.48±.08cd	0.72±.05bc
T5	3.23±.37d	0.37±.10e	0.71±.12bc

CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

of liquid cattle manure. The TN uptake of maize increases with the amount of liquid manure used (Table 9).

The total P uptake of CF, T1, and T2 were considerably greater than the control (CK). The CF treatment P uptake was statistically higher than all treatments. T2 was statistically higher P uptake than T3 and T5. T1 and T4 were also significant to T5 in total P uptake probably due to the higher amount of liquid cattle manure used.

The total K uptake in all treatments was considerably greater than the control (CK), except T4 and T5. There was a statistical difference between treatments. CF, T1 and T2 were statistically different from all treatments. The total K uptake of maize increases with the amount of liquid manure used.

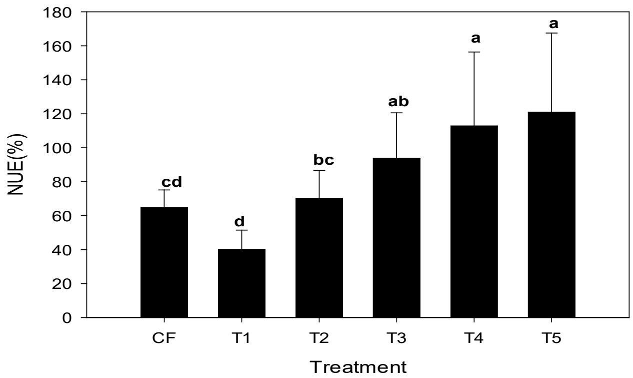

Figure 10: Effect of treatments on NUE of maize. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

Nitrogen use efficiency (NUE): is an expression that describes the relationship between the quantity of N uptake from the soil by the crop and the total of the N fertilizer applied. NUE was 64.7%, 40%, 70%, 93.7%, 112.8% and 120.8% for every N applied treatments with regard to the application of 5.3, 5.12, 2.56, 1.7, 1.25 and 1.02g N plant^{-1} respectively. It decreases with an increasing rate of N application.

Figure 10 Effect of treatments on NUE of maize. CK, unfertilized control; CF, Chemical fertilizer (Farmer practice); T1, Treatment one; T2, Treatment two; T3, Treatment three; T4, Treatment four; T5, Treatment five. All values are reported as mean±SD, n = 10. The values followed by the different letters show statistically significant differences at P<0.05.

Discussion

Characteristics of LCM used in this experiment

Deciding the best rate of animal manure for optimum crop yield and productivity of the soil is very important in continues use of manure. The source and characteristics of liquid manure determines the application rate. Most previous samples of LCM were frequently produced from cattle's, and the nutrient content and its characteristics were not stable, that's why it's challenging to compare the results from various experiments. For example, the TN of LCM as stated was 8.9 for lagoon storage to 49.9 lb/1,000 gals for Indoor pit, respectively.

The same is true even when the source of storage was the same and used at different times. i.e., the physio-chemical properties of LCM obtained from Fengtianbao Fertilizer Company used in the present study were also different. The crop yield was increased by using the LCM in this experiment.

Effect of LCM on soil Physio-chemical properties

The application rate of LCM to the soil depends on its N content, but it is difficult to determine due to the various components of LCM, and the estimated N that would be obtainable for plants uptake throughout the growing period. The crop obtainability of N in LCM is lower than obtainable N in mineral fertilizers. The responses of obtained yield, N uptake and other plant parameters to LCM were lower than mineral fertilizer, which was similar to the present result.

According to Geng, the use of manure is valuable to the soil nutrient balance and enables environmental protection which signifies a respectable method of sustaining crop yield and SOC contents [11]. Therefore, manure is applied as a main soil productivity improvement in sustainable manner. Application of LCM maintains soil fertility at desirable levels [12]. In this result, the soil pH was moderately alkaline. The textural class of the present result was sandy loam soil. Sandy loam soil usually has low organic matter content which results in a low water holding capacity. In the present study, the soil parameters show significant difference in pH, TN, available phosphorus, available potassium, SOM, and SOC after harvest. The Soil total nitrogen may be reduced probably due to the loss of N through NH3 or gaseous form and the conversion of Ammonium to Nitrate and loss by leaching [13]. Aguilera revealed that, the NPK retained in the soil increased with the LCM application rate [14] which was similar to my result.

The use of LCM at a higher rate enhanced soil pH but returned to values the same to control. Soil pH remains the same after nine years of LCM application at the recommended rate. In contrast in my pot experiment the application of LCM reduces the soil pH, the more the application the more pH reduction. The amount of pH was reduced after harvest and other chemical properties were improved than the control due to the nutrient content of liquid cattle manure.

Effect of LCM on yield and yield components

The application of LCM to the soil at similar rates to recommended mineral fertilizer level for crops enhances crop yield, and macro-nutrients uptake [15]. To attain a higher kernel yield application of a large amount of nitrogen is an essential [16]. In my study, the highest kernel yield was obtained under the Chemical fertilizer and manure treatments scores were statistically higher kernel yield than the control (without using any fertilizer). Treatments, CF (5.3g N plant^{-1} from Urea), T1(treatment with 5.12g N plant^{-1} from liquid manure, and T2 (2.56g N plant^{-1} from liquid manure application produced 145.8g plant^{-1} and 132.9g plant^{-1} and 131.3g plant^{-1} of maize kernel yield, respectively and the control (CK) treatment gave minimum yield 86.4 g plant^{-1}. CF, T1, and T2 scored high yields because of the rise in the number of kernels ear^{-1}. In these studies, the rises in kernel yields are mostly dependent on the breeding of high-yield varieties, amount, form and type of fertilizer input.

The yield of maize was affected by four indexes: The number of rows ear^{-1}, kernel number row^{-1}, kernel number ear^{-1}, and 100-kernel weight. It can be seen from the yield components of every different treatment were that the main reason for the lower yield of the control CK, without fertilizer, was the smallest number of kernels row^{-1}, which leads to the lower number of kernels ear^{-1}. The maize yield of the treatments T5, T4, and T3 are also low mainly due to the low N input, weight of 100-kernel, the number of kernels ear^{-1}, respectively low. The main reason for the higher yield of farmers practice (CF) is due to high available N from Urea (5.3g plant^{-1}) and treatments, T1 and T2 (The higher effect of 5.12g N plant^{-1} (with 3.43g available N) and 2.56g N plant^{-1} (with 1.71g available N) from liquid cattle manure. The treatments with higher Nitrogen gave a higher grain yield of 145.8g plant^{-1}, 132.9g plant^{-1}, and 131.3g plant^{-1}, respectively than those produced by the lower rate of liquid manure due to low N input and the control treatment without any fertilizer. It is in line with the findings of numerous researchers [17] who observed that the application of LCM at a level similar to the recommended mineral fertilizer level for crops, increases crop growth, yield, and macro-nutrients uptake. The yields of many field crops can be increased by the application of manure soils. In the present study, ear length was affected by the amount and kind of fertilizer inputs, CF was significant to CK, and the other treatments were statistically similar to CK. But, the ear length of treatments was higher than CK control treatment due to various levels of N fertilizer inputs. In ear diameter, the higher N rate scored higher ear diameter. CF, T1, and T2 were significant to T4, implying that the amount, type, and method of nitrogen application contributes to a more significant ear diameter (Table 7). In the present study, ear length values had shown significant difference probably due to a split application of nitrogen and N rate from both chemical fertilizers for CF and LCM for manure treatments.

Effect of LCM on crop growth parameters and measurements

Leaves are an important photosynthetic part of a plant used to capture light energy to make their food from water and carbon dioxide which makes the plant healthy and grow well. The leaf number of summer maize was 7-9, 9-11, 13-15, 15-17 at 30, 50, 70, and 90 DAS respectively. There was a significant difference among six treatments (one chemical fertilizer, five liquid manure treatments) and control or without using any fertilizer, after 30, 50, 70, and 90 days from the sowing date (Table 3). In this study, the leaf number had shown a significant difference probably because of a split application of nitrogen (two times for chemical and three times for N from liquid manure), N rate, and fertilizer types (in both organic and inorganic forms), have different effects on crop growth [18].

In this study, plant height of maize at, 30, 50, 70, and 90 DAS ranges from 41.6cm-55.1cm, 84.6cm-100.5cm, 134.4cm-162.1cm, and 192.1cm-218cm, respectively. The influence of various treatments on plant height was observed at all plant growth stages from 30 to 90 days from the sowing date. Chemical fertilizer treatment (CF) and T2 were scored higher plant height and T5 scored lowest plant height after 30 days from sowing, CF was significantly different from all treatments after 50 and 70 days from sowing. There was also a significant difference between treatments and the control. This indicates that the plant height was affected by the application of manure treatments (Table 4). This result was agreed with, who stated that significant variation in plant heights between treatments was due to variation in nitrogen and plant density.

In the present result, the stem diameter of maize at 30, 50, 70, 90 DAS was 10.1-14.6cm, 19.1-23.4cm, 20.5-23.7cm, and 20.8-24cm, respectively. There was a statistical difference between treatments and also between treatments and control at 30, 50, 70, 90 days from sowing (Table 5).

The leaves chlorophyll reveals the response of plants to nitrogen absorption and utilization. The maize leaves chlorophyll at 30, 50, 70, and 90 days after sowing ranges from 43.7-51.2, 45.8-53.1, 52.1-61.8mSPU. There was a significant difference between treatments at, 30, 50, 70, and 90 days after sowing and T2 scored higher and CK scored lower chlorophyll after 30 days from sowing. CF was a significant difference from all treatments and scored higher chlorophyll after 50, 70, and 90 days from the sowing date (Table 6). In this result, a significant effect was found among treatments due to split application of nitrogen, N rate, and fertilizer types having different effects on crop growth. The leaves chlorophyll between different treatments was different due to variation in nitrogen inputs [19].

Effect of LCM on nutrient use efficiency

Nitrogen use efficiency was 64.7%, 40%, 70%, 93.7%, 112.8% and 120.8% for each treatments of nitrogen application rate of 5.3, 5.12, 2.56, 1.7, 1.25 and 1.02g N plant^{-1} respectively. The results of this study agree with who described that at a high N application the NUE decreased due to the small increase in kernel yield.

The total nitrogen uptake of maize increases with increasing nitrogen rate for the crop due to the increase in nitrogen concentration in both the Stover and kernel yield as the matter of healthier roots. The nitrogen uptake by maize plant was increased with LCM utilization level. In the present study, the total nutrient uptake was significantly affected by fertilizer inputs and the type of fertilizer used (Table 9). Therefore, it is recommended that the 13.5 L plant $^{-1}$ application rate is more efficient considering yield perspective and also justified for waste reuse and chemical fertilizer replacement. However, it scores yield less than farmer practice (chemical fertilizer), and not good for maize production due to its high sodium concentration in the soil and needs long term research to recommend the rate based on its effect.

Conclusion and Recommendation

Animal manure is the best resource to improve crops yield and soil fertility, and it is very important in continues use of manure. The application rate of liquid cattle manure to the soil depends on its N content, but it is difficult to determine due to the various components of LCM, and the estimated N that would be available for plants uptake throughout the growing period.

The study shows that LCM is a useful fertilizer that can be substitute a mineral fertilizer in maize production and soil productivity. Fertilization with LCM significantly increases maize yield components: kernel number, 100-kernel weight, kernel number per ear, ear length, ear diameter, Stover, the concentration of NPK uptake, and considerably enhanced the yield of maize. The yield of both kernel and Stover was considerably boosted than the control even at low level of LCM and the yield increases with application rate. All treatments (CF, T1, T2, T3, T4 and T5) scored 68.6%, 53.8%, 51.8%, 47%, 39.5% and 37% higher kernel yield than CK respectively. The nitrogen use efficiency (NUE) of each treatment was 64.7%, 40%, 70%, 93.7%, 112.8% and 120.8% for each nitrogen applied treatments with respect to the application of 353Kg N from Urea, 400Kg N, 200Kg N, 132.6Kg, 97.5Kg N and 79.5Kg N from LCM plant^{-1} respectively. In instance of nutrient utilization, the nutrient use efficiency decreases with an increasing the amount of LCM application. The application rate of 13.5 L plant^{-1} boosted yield of maize by 53.8% than the control. It is recommended that the 13.5 L plant $^{-1}$ application rate is more efficient considering yield perspective and also justified for waste reuse and chemical fertilizer replacement. However, it scores yield less than farmer practice (chemical fertilizer), and not good for maize production due to its high sodium concentration in the soil and needs long term research to recommend the rate based on its effect.

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Conflict of interest

The authors have not declared any conflict of interests.

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