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The Effects of a Prototype Liquid Manure Spreader Machine on Nitrogen Losses and Maize Yield

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Abstract: In the present study, the prototype of a splash plate and injection type liquid manure spreader-which is not yet produced in our country-was developed and the effects of different liquid manure applications on nitrogen loss and maize yield were investigated.
In the research, liquid manure was used and the trials were conducted with two different types of manure application equipment, as splash plate and injection tools. In addition, a plot which was fertilized with only mineral fertilizer and a control plot (unfertilized) were included in the trials in order to obtain comparable data.
When the results were examined, it was found that the effect of different liquid manure applications on maize yield was statistically significant ($P<0.01$). The maximum grain yield was obtained from the liquid manure injected plot with 1382 kg da^{-1}. It was found that the rate of nitrogen loss varied between 4-8% and 48-68% in manure injected plots and liquid manure surface applied plot respectively.
Key words: Liquid manure, liquid manure spreader machine, nitrogen loss, maize yield

Prototip Sıvı Ahır Gübresi Dağıtma Makinesinin Azot Kayıplarına ve Tane Mısır Verimine Etkileri

Özet: Bu çalışmada ülkemizde üretimi henüz yapılmayan çarpma plakalı ve gübreyi toprak altına enjekte edebilen bir sıvı ahır gübresi dağıtma makinesinin prototipi yapılarak, farklı gübre uygulamalarının azot kaybı ve mısır verimine etkisi araştırılmıştır.
Denemelerde sıvı ahır gübresi kullanılmıştır. Denemeler iki farklı sıvı gübre uygulayıcısıyla (Çarpma plakalı, Enjeksiyon) yürütülmüştür. Ayrıca mukayese edilebilir değerler elde edebilmek için mineral gübreyle gübrelenmiş parsel ve kontrol (gübresiz) parseli kurulmuştur.
Sonuçlar incelendiğinde, sıvı ahır gübresinin farklı uygulama şekillerinin tane verimi üzerine etkisi istatistikî açıdan önemli bulunmuştur ($P<0.01$). Araştırmada en yüksek tane verim değeri 1382 kg da^{-1} ile sıvı gübrenin enjeksiyonla uygulanmasından elde edilmiştir. Azot kaybı değerlerinin enjeksiyon uygulamasında %4-8, yüzey uygulamasında ise %48-68 arasında değiştiği belirlenmiştir.
Anahtar kelimeler: Sıvı ahır gübresi, sıvı gübre dağıtma makinesi, azot kaybı, mısır verimi

INTRODUCTION

The biggest problem the world faced in the middle of the twentieth century was that adequate amounts of economical food could not be provided to the people to meet the needs of the increasing world population. In order to solve this problem, agricultural policies have aimed at obtaining more output from unit area, and in order to achieve this aim, high yield varieties, monoculture production and intensifying the use of input, particularly water, have been targeted in plant production. Fertilization, which has a significant share in these inputs, will be one of the most important inputs of agriculture in the future, as it was in the past. Considering the present situation, an increase in yield per unit area can only be achieved through fertilization. Fertilization, however, is generally carried out by using mineral fertilizers. Unidirectional applications of mineral fertilizers would cause an increase in the range of saline areas and the degree of salinity. The soils of our country are extremely poor in organic matter (< %1). In addition, according to a study (Dinç et al., 1993) the problem of salinity exists on the 1.5 million hectares of our soils, while another study states that the area of soils facing salinity is 2-25 million hectares (Munsuz et al., 2001). The use of farm manure would yield a very high contribution to our soils considering the problems mentioned above. Farm manure consists of a mixture of the dung or faeces (solid and liquid) of domestic animals collected in barns and farmyards with the material used for bedding, including straw and grass remainders. More than half of the plant nutrients existing in animal feed are transferred to the manure through faeces, for this reason, these manures are rich nutrient sources for plants with regard to the nutrients they contain. Furthermore, farm manure has a substantially high agricultural value, because it increases the fertility, water holding capacity, permeability, ventilation and biological activity of the soil (Balsari et al., 2002). Farm manure consists of two parts as liquid and solid. The liquid form, which is also named as bio-manure, is formed as the result of the disintegration of animal faecal matter in an oxygen-free environment. Liquid farm manure, which has a specific gravity of 1.1 – 1.6 g cm^{-3} and contains 4.7 N kg m^{-3}, 2.4 P kg m^{-} and 5.9 K kg m^{-3}, is an excellent organic fertilizer which can make important contributions to the soil and the plant when implemented (Mikled et al. 2002). The total amount of chemical fertilizers used in our country is 5.516.649 tonnes (Anonymous, 2008). The cost of the chemical fertilizers used to the country's economy is approximately 2.5 billion Dollars. Considering the number of cattle in our country (10.859.942 cattle) (Anonymous, 2008), the daily amount of manure generated by livestock is approximately 450 thousand tonnes. While nearly 290 thousand tonnes of this manure is liquid, 160 thousand tonnes is solid. It has been figured out that in case of using the manure obtained from only cattle in agriculture, approximately 65% of the demand for chemical fertilizers could be met and in case of using only liquid manure 42% of the total manure use would be provided and in this way, 1 billion dollars would be contributed to the economy.

A number of systems are used for liquid manure applications. Among these systems, the use of liquid manure tankers and injectors is common. On the other hand, convenient storage of liquid manure, the use of spreading systems and their performances have not yet been completely investigated and determined. However, it is necessary to pay attention to choosing the appropriate machine in order to achieve the accurate liquid manure application. Furthermore, convenient storage and spreading systems should be used in order to know the amount of nitrogen existing in the liquid manure applied to the product and to prevent nitrogen loss (Chambers et al., 2001, Çarman, 1997). While applying the liquid manure to the soil, the amount of fertilizer lost in the soil surface is found to be smaller through big openers, greater injection depths and low ground speed. The increase of the fertilizer norm values also causes an increase in the amount of fertilizer released into the air (Rahman et al., 2005).

A similar study has not yet been conducted on this topic in our country. The improvement, production and use of liquid farm manure spreader machines need to be enhanced in order to introduce and maintain the wide use of this application, a form of fertilization which is not extensively used in our country.

In the present study, we developed the prototype of a splash plate liquid manure spreader machine which can inject the manure underneath the soil-a type which is not yet produced in our country-and investigated the effect of different manure applications on maize yield and nitrogen loss. In this way, it was endeavoured to introduce the means of utilizing liquid farm manure, which is a good organic fertilizer.

MATERIAL and METHOD

Material

A prototype liquid manure spreader machine, which is not yet produced in our country, was developed in the study. The machine was a mounted-type spreader which could both inject the manure underneath the soil and perform the surface application of liquid manure. The machine is basically composed of a manure storage tank (600 L) mounted on a frame, legs to apply the manure underneath the soil (3 in total), stepless depth adjustment wheels, a splash plate for surface application, a pump for sending the liquid from the tank to the legs or to the splash plate, a spreader that spreads the manure to the legs, a manometer, a return line and a suction line. Some technical characteristics of the machine are presented in Table 1 and the general view of the machine is shown in Figure 1.

Table 1. Certain dimensional characteristics of the liquid manure spreader machine

Dimensions of the machine:	
Storage tank volume (m^3)	0.6
Total width (mm)	1760
Total length (mm)	1450
Total height (mm)	2150
Working width (mm)	2100 (adjustable)
Distance between the legs (mm)	700 (changeable)

Figure 1. The general view of the liquid manure spreader machine used in the trials

Values of certain soil characteristics of the test area where the study was conducted measured before the application and some characteristics of the liquid manure used in the trials are given in Table 2. The material used in the trials was dent corn (Zea mays indentata Sturt) medium early maturing 'BORA' hybrid maize (*Zea mays L. indentata S.*) from FAO 600 maturity group, which is patented in our country and which has been tried and yielded high performance in our region.

Table 2. Some physical and chemical characteristics of the trial field soils and the liquid manure

Characteristic	**Soil**	**Liquid manur**
Clay (%)	38.00	-
Silt (%)	38.00	-
Sand (%)	24.00	-
Texture class	CL	-
Penetration resistance (MPa) (0-20 cm)	0.66	
Shear stress (N cm^{-2})	1.06	
Surface profile irregularity (%)	7.12	
pH	8.05	7.12
EC (µS cm^{-1})	417	1716
Organic matter (%)	2.59	30.2
Aggregate stability (%)	27.07	-
Volume weight (g cm^{-3})	1.23	1.024
Total nitrogen (%)	0.15	0.70

Method

The trials were conducted by using two different liquid manure spreaders (splash plate and injection (crowbar type)) and at an injection depth of 10 cm (Figure 2). In addition, in order to obtain comparable values, a plot fertilized with only mineral fertilizer and a control plot (unfertilized) were established. In the trial, fertilizer norm was assigned by determining the nitrogen content of the liquid manure based on the amount of nitrogen needed by the maize plant (20 kg da^{-1}). Liquid manure was applied twice a year (before planting and at the second hoeing) each time at a norm of 1.5 t da^{-1}. Agricultural procedures other than manure application were performed in the same manner on all plots.

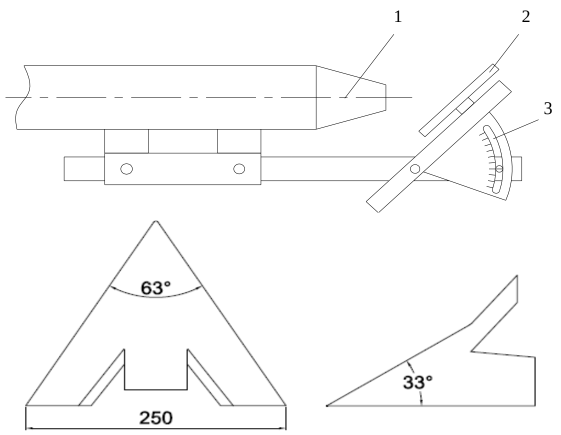

Figure 2. The general view of the splash plate and iinjection equipment (1- Spraying nozzle, 2- Splash plate, 3- Plate position angle adjustment mechanism)

The ground speed of the machine was kept constant at 4.5 km h^{-1}.

Prior to the study, the distribution uniformity of the spreader machine was determined. Collecting boxes made of sheet iron with dimensions of 500x500x170 mm were used for collecting the manure spread in the experiments that were conducted under laboratory conditions (Anonymous, 2004). Manures collected in the boxes after three passes of the tractor were weighed using an electronic scale with a precision of 0.01 g. Distribution pattern graphs were drawn on a computer by using the amount of manure obtained and were given as deviation from the mean (%). The distribution patterns were folded at box width each time and the variation coefficients (%CV) of the distribution obtained after folding were calculated for forward-backward and rotating operations respectively on the computer using a special program. The highest acceptable limit of uniform distribution was taken as %CV≤ 30 (Anonymous, 2004).

Determining nitrogen loss following the liquid manure application

Nitrogen loss was measured following the manure application using a vacuum system with 1 m^2 (0.5x2 m) Plexiglas tunnels closed on the grooves (Figure 3) (Lockyer, 1984).

Figure 3. The system for measuring nitrogen loss

In order to measure nitrogen loss, a wind tunnel was placed on the soil surface for collecting the volatile air from the soil surface right after the manure application and the air collected from the tunnel through a vacuum was passed through bottles containing 3% 100 ml boric acid to catch the nitrogen compounds existing in the air (Smith et al., 2000). Nitrogen values were determined by analyzing the results in the laboratory through titration. The acid existing in the bottle was replaced at the 3rd, 6th, 12th, 24th and 48th hours during the nitrogen loss measurements (Thompson, 2004).

The profile formed on the soil by the machine is one of the highly important factors affecting nitrogen loss (Figure 4) (Rahman et al., 2005). For this reason, the cross-section profile left by the machine during the injection of the manure into the soil was determined through a profile-meter.

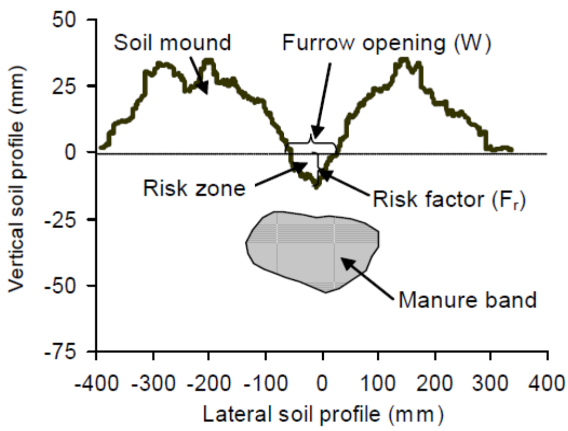

Figure 4. Negative-type soil surface profile

Maize yield

Maize cobs harvested by hand were separated into grains, weighed and the obtained value was converted to yield per decare through calculation. Following the weighing process, the humidity of maize grains was determined and the weights were classified according to humidity (Poehlman, 1987).

The trials were conducted for a period of 1 year with 4 repetitions at Selçuk University Faculty of Agriculture Sarıcalar Application and Research Farm. Plots belonging to each application were prepared as stated and 'BORA' hybrid dent maize was planted with a planting density of 7142 seeds per decare. The dimensions of the plots were regularized as 5x50 =250 for all the applications. For all the applications, the data that was considered to be important regarding yield values were subjected to statistical analysis (Düzgüneş et al., 1987). The means that were found to be significant were compared by LSD test using **MSTAT-C** software.

RESULTS and DISCUSSION

The distribution regularities of the machine were determined and optimized for different liquid manure norm values and two different types of spreaders respectively (legs injecting the manure underneath the soil and splash plate for surface application). The variation coefficient (%CV), which is the indicator of the distribution regularity between the legs, was found to be 1% for the legs injecting the manure underneath the soil. The graph of the surface application (splash plate) distribution pattern is given in Figure 5.

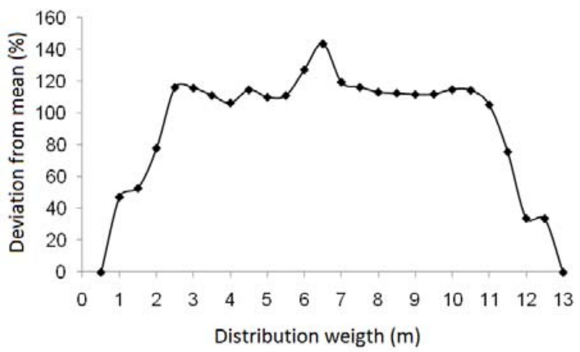

Figure 5. Splash plate distribution pattern

The minimum variation coefficient, effective working width and variation limits of working width in forward-backward and rotating operations of the splash plate were found to be %CV 11.61, 10.5 m, 9.5…11 m and %CV 9.05, 10.5 m, 8.5…11.5 m respectively.

The nitrogen losses that emerged during the liquid manure implementations in the trials are presented in Figure 6, and the profile left on the soil by the leg during the injection of the manure into the soil is presented in Figure 7.

Before planting, liquid farm manure containing 0.7% nitrogen was applied to the plots. Nitrogen loss was started to be measured with manure application and of the nitrogen applied to the soil, approximately 4% was lost during the injection application and approximately 48% was lost during the surface application through vaporizing (air temperature 22 ^oC). At the second hoeing, liquid farm manure containing 0.6% nitrogen was given to the plots and approximately 4% of the nitrogen was lost during the injection application and approximately 48% was lost during the surface application through vaporizing (air temperature 34 ^oC).

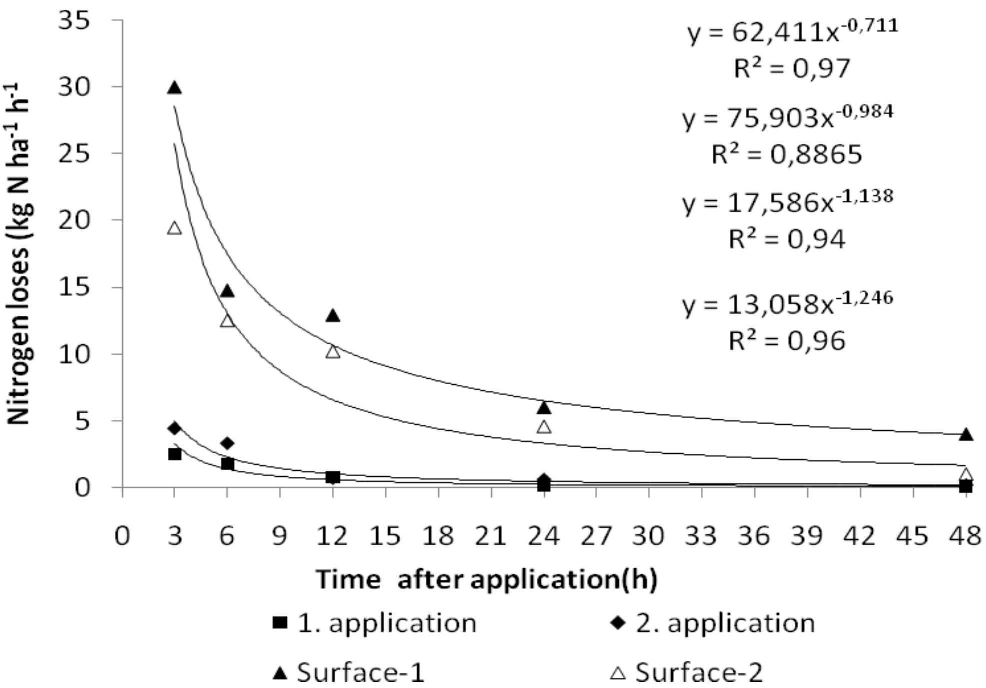

Figure 6. Nitrogen Losses due to liquid manure applications

Table 3. Values relating to yield and yield factors determined through different forms of applications

Applications	Grain yield (kg/da)	Plant height (cm)	Cob length (cm)	Cob diameter (mm)	Grain number per cob (adet)	Grain weight per cob (g)	Grain cob ratio (%)	Thousand grain weight (g)	Hectolitre weight (kg)
Injection	1382 a*	244	18.17	53.80	591.2	268.7	82.03	404.11	70.00
Surface	829 b	202	14.40	49.00	454.9	226.6	80.59	391.64	69.80
Mineral fert.	1202 a	230	18.05	52.70	587.2	267.7	80.88	405.20	68.95
Control	664 b	190	14.67	47.80	448.6	164.9	79.66	321.03	64.42

*LSD (%5): 251.61

When Figure 6 is examined, it can be seen that maximum nitrogen loss was observed at the 3rd and 6th hours and the mentioned loss decreased during the following hours. It is seen that nitrogen loss significantly decreased and came close to zero particularly after the 24th hour. Similar results are presented in a number of studies on nitrogen loss emerging following liquid manure applications (Smith et al., 2000; Thompson and Meisinger, 2004; Sharpe et al., 2004). It can be seen that nitrogen loss was higher in the 2nd manure applications compared to 1st liquid manure applications for both forms of manure. It is thought that this increase in nitrogen loss was the result of high air temperature. High air temperature causes significant increases in nitrogen loss (Thompson and Meisinger, 2004; Sharpe et al., 2004; Sommer et al., 2004).

When Figure 6 is examined, it can be seen that nitrogen loss through surface application is 8.5-12 times higher compared to injection type application. Nitrogen losses up to 90% in surface applications are reported in a number of similar studies. In this study, nitrogen loss values that were observed depending on the type of leg used for injecting liquid manure and working depth were found to be substantially lower compared to other studies.

When Figure 7 was examined, the risk factor of the application was found to be approximately 35 mm. In similar studies, the risk factor values are reported to be close to our findings depending on the depth of application (Rahman et al., 2005). An increase in the risk factor causes an increase in the amount of manure that evaporates into the air. An increase in injection depth causes a decrease in the risk factor.

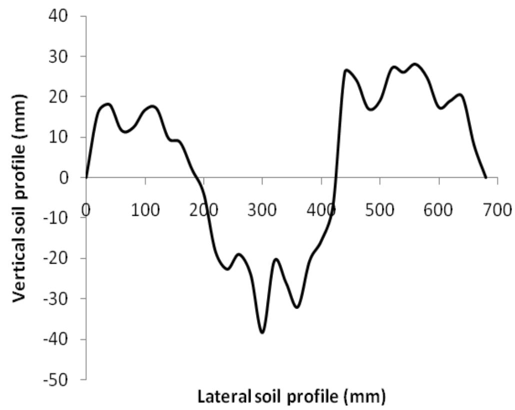

Figure 7. The profile left on the soil by the leg during injection

The effect of different forms of liquid manure applications on grain yield was found to be statistically significant (P<0.01) (Table 3). The highest grain yield was obtained as 1382 kg da^{-1} with the application of liquid manure through injection (Figure 8).

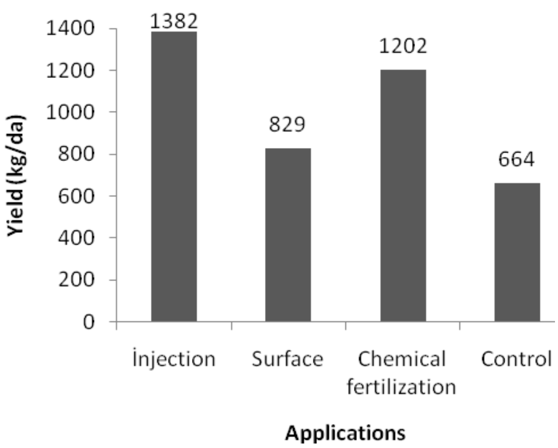

Figure 8. Yield values for different applications

The main nutrients of the maize plant are macro nutrient elements like N, P and K and micro nutrient elements which the soils of the Central Anatolia substantially lack. Farmers who cultivate maize in the Central Anatolia Region use fertilizers without concern presuming that they can get higher yield by using more fertilizer. This attitude both affects the soil structure negatively and inflicts a financial burden on the farmers.

The positive effect of farm manures on grain yield is based on the increase in organic matter caused by the nutrient elements and that compaction and ventilation of the soil creates a suitable environment for maize growth. In fact, Dahiya and Singh (1980) and Laddha et al. (1984) stated that organic matter was a source of nutrient for plants, besides, it was effective on productivity owing to its quality to improve the physical, chemical and biological characteristics of the soil.

The yield parameters and related values obtained through different applications during the trials are presented in Table 3.

In the study, the highest plant height was achieved as 244 cm with the application of liquid manure through injection, while the lowest plant height was observed in the control plots. An increase in plant height also causes an increase in the leaf area per plant, the number of leaves and consequently the assimilation area. The increase of assimilation area positively affects grain yield (Mehta and Sarkar, 1992). In the study, the N provided by the liquid farm manure had a positive contribution to the increase of plant height.

In the study, the highest cob length and cob diameter were obtained with the application of mineral fertilizer and liquid manure through injection in parallel with grain yield. Cobs were found to be smaller in the surface application and the control plot. Cob length and cob diameter are yield components that directly affect the yield of maize (Akçin et al., 1993). Grain numbers per cob and grain weight per cob are important yield components that are related to cob size and directly affect yield. In the applications, the highest grain number and weight per cob was obtained with the application of mineral fertilizer and liquid manure through injection in parallel with grain yield.

When the applications were compared in terms of thousand grain weight and hectolitre weigh, the highest values were obtained with the application of mineral fertilizer and liquid manure through injection in parallel with grain yield.

As the result of the evaluations, it is concluded that farm manure in liquid form can be used as a substitute for mineral fertilizer. Gomez and Gonzalez (1979) stated that there was not a statistically significant difference among the commercial urea fertilizer, fresh liquid and fermented liquid manures applied to vegetables and an increase was observed in product yield depending on increasing doses of nitrogen. Mikled et al., (2002) put forth that liquid manure could be used alone or by mixing with chemical fertilizers for vegetable production. The results of 2-year trials conducted by the same researchers showed that the application of fermented liquid manure at different norms caused a higher increase in yield and nutritive values compared to chemical fertilizers.

Liquid manure, which is also named as bio-fertilizer, is a valuable resource owing to its important role in increasing soil fertility.

In terms of business management, the surface applications of liquid manure are considered to be advantageous. However, the vaporization of the applied manure into the air in high proportions and the resulting significant decrease in yield show that this form of application is not necessarily convenient.

Farm manure has a significant potential in our country in parallel with animal production. However, farm manure is not sufficiently used in our country due to the economic expenses required for displacing the manure out of the farm, storing and using it on the field, the need for labour for the mentioned procedures and particularly its use as fuel in rural areas.

In conclusion, the following evaluations can be drawn:

- The nitrogen loss values of the liquid manure spreader machine used in the study were found to be substantially lower compared to the values presented in the literature.
- The profile left on the soil by the machine during the injection of the manure into the soil, in other

words, the risk factor shows similarity to the values presented in the literature.

- It was observed that the surface application of the liquid farm manure caused a higher rate of nitrogen loss compared to its application under the soil.
- In terms of plant yield, it was determined that the controlled application of liquid farm manure could be used as a substitute for mineral fertilizer.

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