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Comunication

Modes of application of cattle manure doses on green ear yield and corn grain yield

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ABSTRACT

Broadcasting application of cattle manure increases green ear, corn grain, and forage yields of corn cultivars, but only at high doses, i.e., at rates ranging from 40 t ha^{-1} to 60 t ha^{-1}. Demand for this fertilizer is very high and prices tend to increase. In addition, doses considered economic are relatively low, around 8 t ha^{-1}. It is possible that more effective application methods may reduce the required amount of the fertilizer. The objective of this study was to evaluate the effects of application modes (by broadcasting or in the planting furrow) of cattle manure doses (0, 2, 4, 6, 8, and 10 t ha^{-1}) on green ear yield (in one experiment) and grain yield (in another experiment) of the corn cultivar AG 1051. The (factorial) experiments were arranged in a randomized block design with eight replicates. Manure doses and fertilizer mode of application did not influence plant and ear heights, total number and weight of ears, and the number and weight of marketable ears, both unhusked and husked. Manure doses did not influence grain yield and its components, but manure broadcast application determined higher grain yield than furrow application, a result obtained mainly because of the positive effect on 100-grain weight.

Key words: *Zea mays* L., green ear quality, organic fertilization

RESUMO

Modos de aplicação de doses de esterco bovino nos rendimentos de espigas verdes e de grãos do milho

O esterco bovino aplicado a lanço aumenta os rendimentos de espigas verdes, de grãos e de forragem do milho, mas somente em doses elevadas; isto é, de 40 a 60 t ha^{-1}. A procura por esse fertilizante é muito grande, e o preço tende a se elevar. Além disso, as doses consideradas econômicas são relativamente baixas, em torno de 8 t ha^{-1}. É possível que métodos de aplicação mais eficientes possam reduzir a quantidade requerida. O objetivo deste trabalho foi avaliar os efeitos do modo de aplicação (a lanço ou no sulco de plantio) de doses (0, 2, 4, 6, 8 e 10 t ha^{-1}) de esterco bovino sobre os rendimentos de espigas verdes (em um experimento) e de grãos (em outro experimento) do cultivar de milho AG 1051. Os experimentos (fatoriais) foram realizados no delineamento de blocos ao acaso, com oito repetições. As doses e o modo de aplicação do esterco não influenciaram as alturas da planta e de inserção da espiga e o rendimento de espigas verdes. As doses de esterco também não influenciaram o rendimento de grãos e seus componentes, mas a aplicação a lanço determinou maior rendimento de grãos que a aplicação em sulcos; que resultou, principalmente, do seu efeito positivo sobre o peso de 100 grãos.

Palavras chave: *Zea mays* L., qualidade de espigas de milho verde, adubação orgânica.

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INTRODUCTION

Corn is one of the most important crops in the Brazilian Northeast, considered as a subsistence crop and cultivated under dryland conditions. Support policies for irrigated agriculture by the State and Federal governments have increased the irrigated area cultivated with corn and currently the crop is cultivated even by large fruit-growing companies. During the off-season, from July to December, there is a higher interest in irrigated corn cultivation, since the demand for green ears and grain is greater than the supply, with increased prices. During this period, almost three crops can be obtained. Such intensive cultivation results in physical, chemical, and biological problems to the usually very low-fertile soils. Extensive areas in numerous regions are abandoned after the consequent degradation that follows several cultivations (Biederbeck *et al.*, 1997).

Cattle manure applied by broadcasting in corn increases green ear yield (Silva *et al*., 2004), grain yield (Silva *et al*., 2004; Menezes, 1993), and forage yield (Tran & N'Dayegamiye, 1996), but only at high doses, i.e., 40 t ha^{-1} (Silva *et al*., 2004) to 60 t ha^{-1} (Menezes, 1993). Currently, the demand for this fertilizer is very high and prices tend to increase. On the other hand, doses considered economic are relatively low, around 8 t ha^{-1} (Silva *et al.*, 2004). It is possible that more effective application methods will help reduce the required amount of cattle manure for maize production.

The term "placement" banding is used when nutrients are placed below and along the crop rows within a certain distance (Rasmussen, 2002). Placement of fertilizers reduces the risks of microbial immobilization of nitrogen and phosphorus, physico-chemical fixation of P and, in case of ammonium, early nitrification into leachable nitrate (Wetselaar *et al*., 1972) as compared to the broadcast application of fertilizers. When fertilizers are placed close to the root systems, placement can further promote a timely interception of nutrients by crops (Schröder *et al*., 1997). Maize crops are commonly grown at row spacings of 70 – 80 cm and can respond markedly to fertilizer placement probably due to the initially incomplete exploitation of the soil by their roots (Schröder *et al*., 1996). Placement of mineral nutrients has been shown to improve early crop growth and yield because of a shorter distance from the plant to the nutrients and improved availability of the nutrients (Cochran *et al*., 1990). A number of studies (Basso *et al*., 2004; Sharpe *et al*., 2004) show that the application of many types of manure onto the soil surface cause nitrogen losses by ammonia volatilization; such losses will depend on the dose and type of manure applied and on environmental conditions (Basso *et al*., 2004).

In many intensive agricultural systems, liquid manure (slurry), which is a mixture of animal urine and faeces, is a major source of plant nutrients. Sawyer *et al.* (1991) observed a negative relationship between the yield of maize and the lateral distance between the plant rows and the slurry injection slot. Yields were depressed by 8 % when maize was planted in between the slots instead of next to the slots.

If placement contributes to a better availability of the cattle manure, either a higher yield or a similar yield could be obtained at a lower dose of cattle manure. Similar considerations were made by other authors for nitrogen (Everaarts & Moel, 1995) and phosphorus (Barreto & Fernandes, 2002) fertilizers. No papers were found in the literature about the influence of solid cattle manure application method on maize yield.

The objective of this work was to evaluate the effects of modes of application of cattle manure doses on green ear yield and dry grain yield of corn.

MATERIAL AND METHODS

Two similar experiments, identified as experiment-1 (evaluation of the green ears yield) and experiment-2 (evaluation of the grain yield) had been ahead carried through during the period of February the May of 2004 (the sowing of the experiment-1 was effected in 11/02/04 and of the experiment-2, 8 days later), under conditions of dry land, but with possibility of sprinkler irrigation, when necessary.

The experiments were conducted at Fazenda Experimental "Rafael Fernandes" (experimental farm), of Universidade Federal Rural do Semi-Árido (UFERSA), located at 5º 11' S, and 37º 20' W, elevation 18 m.a,s.l.. The water depth required for corn (5.6 mm) was calculated considering an effective depth of the root system of 0.40 m. Irrigation time was based on the water retained by the soil at a tension of 0.04 MPA. An irrigation shift of 1 day was established. The irrigations started after planting and were suspended one day before each harvest.

The experimental soil, classified as euthrophic Red-Yellow Argisol (Embrapa, 1999 b) and as Ferric Lixisol according to the Soil Map of the World (Fao, 1988), was prepared with two plowings and fertilized with 30 kg N (urea) 60 kg of P_2O_5 (simple superphosphate) and 30 kg of K_2O (potassium chloride), per hectare. The fertilizers were placed in furrows located alongside and below the sowing furrows.

The six cattle manure doses (0, 2, 4, 6, 8, and 10 t ha^{-1}, dry basis) were applied manually by broadcasting (and incorporated to the soil) or over chemical fertilizers placed in the furrows. The furrows were later covered with soil. An analysis of the applied manure (Embrapa, 1999 a) indicated: pH (H_2O) = 6.8; Ca = 17.00 $cmol_c$ dm^{-3}; Mg = 2.30 $cmol_c$ dm^{-3}; K = 9.22 $cmol_c$ dm^{-3}; Na = 2.72 $cmol_c$ dm^{-3}; Al = 0.00 $cmol_c$ dm^{-3}; P = 431.0 mg dm^{-3}; organic C = 10.12 %; Org. Mat. = 17.46 g kg^{-1}.

Corn seeds were planted manually, at a spacing of 1.0 m × 0.4 m, using four seeds/hole. A thinning operation was performed 20 days after planting, leaving the two more vigorous plants in each hole. Therefore, after thinning the experiment showed a population density equivalent to 50.000 plants ha^{-1}. Corn cultivar AG 1051 is a short sized, super-early double hybrid with yellow dent grain. Pest control was carried out using two deltamethrin sprays (250 mL ha^{-1}), performed at 7 and 14 days after planting.

Weed control was accomplished by means of two hoeing operations, performed at 20 and 45 days after planting. After each weeding operation, the experiment was fertilized with 30 kg N ha^{-1} (ammonium sulfate).

A randomized block design with 8 replications, arranged as a complete factorial experiment was used. Each experimental unit consisted of four 6.0 m-long rows. The usable area was considered as the space occupied by the two central rows, with the elimination of plants from one pit at each end.

The analyses of variance and regression were performed using the software programs developed by Universidade Federal de Viçosa (SAEG, 1997) and by Jandel Scientific (1991), respectively.

Experiment - 1

The analysis (Embrapa, 1999 a) of a sample of the experimental soil indicated: pH (H_2O) = 6,6; Ca = 1,90 $cmol_c$ dm^{-3}; Mg = 0,40 $cmol_c$ dm^{-3}; K = 0,10 mg dm^{-3} ; Na = 0,18 $cmol_c$ dm^{-3}; Al = 0,05 $cmol_c$ dm^{-3}; P = 4,0 mg dm^{-3}; organic C = 0,47 %; Mat. Org. = 0,81 g kg^{-1}.

Four green corn harvests were carried out, with two or three day intervals, the first at 70 days after planting. Green corn yield was evaluated by the number and total weight of green ears with husks and by the number and weight of marketable ears with and without husks. Marketable ears with husks were considered to be those measuring 22 cm or more in length, without stains or evident signs of attack from disease or pests. Marketable ears without husks were considered to be those measuring 17 cm or more in length, with grains and appropriate for commercialization. After harvesting of the green ears, plant height, ear height, length and width and the area of four leaves were evaluated. Plant height and ear height were evaluated in ten randomly chosen plants among the plants used in the evaluation of green ear yield. Plant height was taken from soil level to the highest leaf blade insertion. Ear height was measured from soil level to the ear insertion node.

Experiment - 2

The results of soil analysis (Embrapa, 1999 a) were: pH (H_2O) = 7,4; Ca = 2,50 $cmol_c$ dm^{-3}; Mg = 0,30 $cmol_c$ dm^{-3}; K = 0,12 mg dm^{-3}; Na = 0,11 $cmol_c$ dm^{-3}; Al = 0,00 $cmol_c$ dm^{-3}; P = 5,0 mg dm^{-3}; organic C = 0,55 %; Mat. Org. = 0,94 g kg^{-1}.

Ripe ears were harvested 105 days after sowing, when grain showed moisture content of approximately 20%. The ears were then husked and left to dry under the sun for approximately 72 hours and threshed by hand. After weighing the grain, a 100 g sample was taken to estimate moisture content. Based on the determined moisture content , grain weight was corrected to a moisture content of 15.5%. Number of grain per ear was estimated based on 20 ears, and the 100-grain weight was estimated based on five samples of 100 grain. After the dry ears were harvested, ten plants were taken at random from the usable area of each plot to evaluate plant height (distance from the soil level to the insertion point of the highest leaf blade) and ear height (distance from the soil level to the insertion point of the first ear).

RESULTS AND DISCUSSION

The application of manure doses produced no effects on the traits evaluated in experiments 1 and 2. In experiment-1, trait means were: 190 cm (plant height, Coefficient of Experimental Variation = CV = 6%); 104 cm (ear height, CV = 6%); 50120 (total number of green ears ha^{-1}, CV = 4%); 47402 (number of marketable unhusked green ears ha^{-1}, CV = 6%); 38583 (number of marketable husked green ears ha^{-1}, CV = 19%); 14785 kg ha^{-1} (total green ear weight, CV = 12%); 14365 kg ha^{-1} (marketable unhusked green ear weight, CV = 16%); and 7820 kg ha^{-1} (marketable husked green ear weight, CV = 21%). In experiment-2, means were: 164 cm (plant height, CV = 11%); 70 cm (ear height, CV = 14%); 47942 (number of ears ha^{-1}, CV = 8%); 443 (kernels ear^{-1}, CV = 11%); 27.9 g (100-kernel weight, CV = 11%); and 5503 kg ha^{-1} (grain yield, CV = 22%). Several types of organic fertilizers are able to increase grain yield in maize, including cattle manure (Menezes, 1993). Cattle manure also increases green ear yield (Silva *et al*., 2004) and yield of the above-ground part of corn plants grown for silage (Tran & N'Dayegamiye, 1996). The discrepancy between these results and those obtained in the present work could be due to several factors, including the evaluated doses and manure composition, soil type, cultivar (Silva *et al*., 2004), and irrigation. In a few cases where a corn response to manure was obtained, doses of four (Silva *et al*., 2004) to six times (Menezes, 1993) the maximum dose used in the present work were tested. It is likely that the manure doses used in the present study did not interfere with green ear yield and corn grain yield since that mineral fertilization was per se sufficient to meet corn crop's nutritional demands.

There was no cattle manure application mode effect on plant height and ear height, or on green ear yield. However, manure application via broadcasting (5885 kg ha^{-1}) provided higher grain yield than manure application in the furrows (5129 kg ha^{-1}). This difference was mainly due to the significant difference in 100-kernel weight (28.5 g *versus* 27.2 g), but was also due to non-significant differences in the other two yield components (number of ears ha^{-1} and number of kernels ear^{-1}). For broadcast application, the means for those two components were 48689 and 453, respectively. For furrow application, the corresponding means were 47194 and 432 (Tables 1 and 2). The difference in effect of the cattle manure application modes on green ear yield and grain yield was caused by at least two reasons. First, green ears and grain are differently-exploited products. Ears considered worthless as green corn can be perfectly used when the goal is to produce dry grain. Second, dry corn remained in the field for at least 20 days longer than green corn and could make of the best of the treatment effects. Incidentally, this

Table 1. Means (of 6 cattle manure doses and 8 replicates) for the total number and weight of marketable green ears, unhusked ears, and husked ears of corn cultivar AG 1051, in relation to application modes used with cattle manure doses.

Mode of cattle manure application	Heights (cm)		Number of green ears ha^{-1}			Green ear weight (kg ha^{-1})		
	Plant	Ear insertion	Total	Marketable unhusked	Marketable husked	Total	Marketable unhusked	Marketable husked
Broadcasting	191	105	50384	47815	39349	15131	14688	7990
In furrow	188	103	49855	46988	37817	14438	14041	7650
CV, %	6	6	4	6	19	12	16	21

Table 2. Means (of 6 cattle manure doses and 8 replicates) for number of ears/ha, number of kernels/ear, 100-grain weight, and grain yield of corn cultivar AG 1051, in relation to application modes used with cattle manure doses. [1]

Mode of cattle manure application	Plant height (cm)	Ear height (cm)	Number of ears ha^{-1}	Number of grains ear^{-1}	100-grain weight (g)	Grain yield (kg ha^{-1})
Broadcasting	165 a	70 a	48689 a	453 a	28.5 a	5885 a
In furrow	162 a	70 a	47194 a	432 a	27.2 b	5120 b
CV, %	11	14	8	11	9	22

[1] For each trait, means followed by the same letter do not differ at 5% probability by Tukey test.

is suggested by the positive influence of manure application mode on 100-grain weight. Broadcast application would provide better grain filling than in-furrow application.

Corn dry matter accumulation takes place in a continuous manner until the grain maturation stage is reached, and a more intense accumulation period will occur near flowering (Cantarella & Duarte, 2004). Daily dry matter accumulation rates show two distinct peak periods of aerial accumulation. The first, during vegetative growth when the potential ovule number is being established, shows maximum rates of dry matter accumulation for lower leaves, upper leaves, and stalk and tassel fractions (Karlen *et al.*, 1988). The second peak, which occurs during grain fill when final yield is being determined, shows maximum rates of dry matter accumulation for ear and shank fraction. Aerial P accumulation rates of corn peaked during latter vegetative growth and after dropping at pollination, increased linearly throughout most of the grain-fill period. The negative rates shown for leaf and stalk fractions after approximately 750 growing degree units reflect translocation of P from vegetative plant parts to the developing grain (Karlen *et al.*, 1988). It is likely that the 100-kernel weight difference observed when manure was applied by broadcasting was due to the time elapsed between plant emergence and grain harvesting, which was sufficient for the plants to utilize P from the manure applied on the soil surface. Because of the low organic matter content in the experimental soil, the P applied in the furrow may have been used during the initial development stages of corn.

The higher effectiveness of broadcasting fertilization relative to in-furrow fertilization in bean crops was attributed to the smaller concentration of unrotted manure in direct contact with the plant (Bem *et al.*, 1981). Since rotted manure was applied in the present work, two reasons are indicated to explain the superiority of broadcast fertilization in relation to in-furrow fertilization. First, it is possible that in-furrow fertilization benefited a smaller proportion of the roots, although more intensely, caused by a greater proximity with a smaller proportion of roots. On the contrary, owing to manure incorporation, fertilization by broadcasting would benefit a higher proportion of roots, although less intensely. Second, broadcast fertilization would provide a larger and better-distributed root system. This was verified for P_2O_5 broadcast application in corn, in contrast with application in furrows (Barreto & Fernandes, 2002).

CONCLUSIONS

Therefore, it can be concluded that: a) Manure doses and mode of application of the fertilizer did not influence plant height and ear height, total number and weight of ears, and the number and weight of marketable ears, both unhusked and husked; b) Manure doses did not influence grain yield and its components, but manure broadcast application determined higher grain yield than furrow application, resulted mainly of the positive effect on 100-grain weight.

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