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Ammonia volatilization in corn crop as a result of the application of different nitrogenous fertilizers

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The experiment was carried out in a greenhouse with samples of Eutroferic Red Latosol. On each of these samples, an amount of 800 mg/kg of N was superficially added in the soil. The experiment consisted of five industrial sources of nitrogen, urea (45% of N), urea plus (45% of N), ammonium sulfate (20% of N and 24% of S), Yarabela® (27% of N) where we assessed the volatilization 1, 2, 5, 7, 10, 14, 18 days after the application of the doses. Two methodologies were tested, semi-open static system and the method developed by Miyazawa (2007). After the volatilization assessment of each source, we cultivated a corn plant on each vase for 30 days to evaluate the residual effect of the fertilizer in the crop development through the plant height, stem diameter, dry biomass production of the aerial part and content of N in the vegetal tissue of the aerial part. The urea and the urea plus showed higher volatilization in both ammonium collecting systems and the ammonium sulfate and Yarabela® had the lower volatilization rate. The spectrophotometer detected low levels of nitrogen in comparison to the distillation method.

Key words: Nitrogen, volatilization, urea, residual effects.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most economically important crops and one of the most studied due to the nutritional value of the grain, considering its importance in human and animal feed and its raw material for industry. Among the various factors which contribute to the low productivity, the incorrect management of mainly nitrogenous fertilizers has stood out (Portugal 2012).

According to Silva et al. (2005) nitrogen is the most required nutrient by corn crop, and the dose to be applied may vary depending on the preceding crop, the expected

grain yield and the content of organic matter in the soil. The loss of nitrogen by volatilization of ammonia (NH₃) into the atmosphere is one of the most important factors responsible for the low efficiency of urea applied to the soil surface. In order to provide ammonia volatilization, the presence of ammonia and high pH simultaneously is necessary in the soil (Ernani et al., 2001). The nitrogen losses to the environment are associated with the concentration of soluble nitrogen forms or shapes which is more susceptible to losses. One way to increase the

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Table 1. Chemical and physical analysis of the soil.

P	M O	pH CaCl ₂	H+Al ₂	Al ³⁺	K+	Ca	Mg ²⁺	SB	CTC	V
Mg dm ⁻³	g dm ⁻³	0.01 mol L ⁻¹	Cmol _c dm ⁻³							%
18.45	23.24	5.63	2.98	0.00	0.75	6.69	2.06	9.50	12.48	76.12
Particle size analysis										
Sand%			Silt%			Clay%				
60			15			25				

(1)pH in CaCl₂, the ratio 1:2.5, (2)Extractor kCl mol L⁻¹, (3)Extractor calcium acetate 0.5 mol L⁻¹ pH 7.0, puller Mehlich⁻¹, the hydrometer method (EMBRAPA, 2009).

efficiency of nitrogen fertilizers is the use of slow or controlled release fertilizers. To minimize losses and increase productivity in a profitable and sustainable manner using nitrogen sources, formulas were developed with slow release of nutrients which reduce the losses that normally occur with the use of urea. This gradual release of nutrients is achieved by coating the nitrogen fertilizer with polymers, increasing crop yields and fertilizer efficiency (Cantarella, 2007).

Leon (2008) in ammonia volatilization resulted from the application of urea in corn, verified reduction of nitrogen volatilization and urease activity for the treatments in which was used urea coated with polymer when compared to the conventional urea in the fertilization in the corn crop. In this sense, Sousa and Loubato (2004) advocated that the quality of the fertilizer, the type of solute and the time of application of the fertilizer are factors associated with soil moisture, the cultivated plant species and crop management, which can interfere with fertilization efficiency and cause loss of nutrients and consequently waste of financial resources. However, according to Lara Cabezas and Trivelin (1990), it is possible to estimate the losses by soil ammonia volatilization from the application of nitrogen fertilizers through direct or indirect methods. One way to verify the dynamics of nitrogen, from the nitrogen sources in the soil, is made through the study of nitrogen transformations in soil with the use of stable isotopes. To determine the loss of NH₃ by volatilization coming from nitrogen fertilizer in Brazilian conditions, researchers have developed NH₃ collectors to volatilization measures. Indirect methods can be carried out through the use of isotopically labeled fertilizer (¹⁵N), isotopic measurements show high cost, but they can be used in the calibration of direct methods using collecting chambers (Trivelin and Franco, 2011).

The closed-static systems, closed-dynamic and static semi-open are used in the determination by direct methods. Closed systems may make it impossible to obtain observations of volatilization under natural conditions, because they modify the environment at the soil surface (Lara Cabezas and Trivelin, 1990). The collectors described by Nönmik (1973), with static semi-

open system, are used in field studies. The semi-static open collector, however, also has limitations. These limitations were evaluated by Lara Cabezas and Trivelin (1990), who found that the presence of the semi-static open collector system influenced significantly, by reducing the percentage and amount of volatilized ammonia of the fertilizer. Thus, it can be verified, the importance of using correction factors to determine the static semi-open collector, the N-NH₃ volatilized (Mattos, 2011). Considering the importance of studying different methods to assess the quantity and ammonium speed volatilized by different nitrogen sources, this study aimed to evaluate the amount of ammonia volatilized from each source of N tested by two methods, the static semi-open system and the method developed by Miyazawa (2007).

MATERIALS AND METHODS

The experiment was conducted in the soil fertility laboratory and mineral nutrition of Plants at Universidade Estadual do Oeste do Paraná - UNIOESTE, Campus de Marechal Cândido Rondon / PR. For each vase, we used 6 kg of an Eutrofic Red Latosol (Table 1). On each of these vases, it was added 800 mg/kg of N in the soil surface, where the volatilization was evaluated within 18 days of five sources of N: Urea (45%), ammonium sulfate (20% N and 24% O) Yarabela® (27% N), urea plus (46% N) and super N (45% N).

Five industrial sources of nitrogen were tested by two methodologies applied in coverage and witness, each treatment was composed by four repetitions, totaling 40 vases. The capture of volatilized NH₃ was made by two methods; one of them was the method in closed chambers developed system. For this system, we used transparent plastic bottles of polyethylene terephthalate (PET) with capacity of 2 L and basal diameter of 10 cm. The bottles were sealed at the top, with their bases removed, so that the gases enter therein after their introduction to the soil. Inside the middle part of them, it was placed a plastic centrifuge tube of 50 ml, which is suspended by a wire bracket connected at its upper part, fixed by the lid. Inside this tube it was placed H₂SO₄ solution (0.05 mol L⁻¹), glycerin (2%, v/v) and a strip of filter paper (2 × 20 cm), in order to increase the contact surface of NH₃ with H₂SO₄, according to the method described by Miyazawa (2007). The ammonia retained on the paper was determined by salicylate blue spectrophotometry method (Miyazawa, 2007), salicylic acid 5% solution: 50 g of salicylic acid, 50 g of Na citrate and 21 g of NaOH in 100 ml flask and the remaining volume was completed with water, Na nitroprusside solution in 0.1%: 0.2 g of Na nitroprusside in 200 ml of H₂O and 0.15%: 6 ml of NaOCl 5% NaOCl in 200 ml of

H₂O. In a test tube we added 1 ml of the sample, 1 ml of the salicylic acid solution, 1 ml of Na nitroprusside solution in 0.1%, 1 ml of 0.15% NaOCl solution and 6 ml of water and then the test tubes were agitated and after 60 min the spectrophotometer reading at 697 nm was made. The NH₃ retained on the paper was also determined by vapor dragging, in semi-micro Kjeldahl apparatus (Tedesco et al., 1995).

The other form of assessment of the volatilization of N was by a semi open static system proposed by Nömmik (1973) with some modifications described by Marcondes (2007). Collectors were made with PVC pipes with a diameter of 15 cm, containing two polyurethane foam discs soaked in 50 ml of sulfuric acid 0.25 mol, more Glycerin 3% (v/v). The amount of volatilized N-NH₃ was determined by drag vapor in semi-micro Kjeldahl apparatus (Tedesco et al., 1995). The foams were exchanged in the same time interval when performed by Trivelin (2002), and the volatilization of NH₃ was evaluated at 1, 2, 5, 7, 10, 14, and 18 days after application of treatments, in each of the experiments. During the collection period, the soil moisture was maintained between 70% of water retention in the soil. The collectors were taken to the soil fertility laboratory and mineral nutrition of plants for evaluations. The determination of ammonia retained in the absorber was performed by distillation and titration. The foam of each sample was cut in 2 pieces and placed in a distiller balloon with 1-liter capacity, where it was also added about 100 ml of distilled water and 20 ml of NaOH. We collected the distillate volume containing ammonia retained by the absorber, in a boric acid 2% solution titrated with standardized HCl solution.

After assessing the volatilization of each source, we cultivated a corn plant in each vase to evaluate the residual effect of the fertilizer. After 30 days of cultivation, we evaluated the growth of plants through the assessments of height, plants length, stem diameter and dry biomass production of the aerial part. We also evaluated the N content in the aerial part of the plant tissue according to Tedesco et al. (1995), which consists of the digestion with H₂O₂ and H₂SO₄ and distillation by vapor dragging into semi-micro Kjeldahl apparatus. We used simple linear correlation analysis (Pearson) to determine the relationship between the collecting systems and methods for the determination of N-NH₃. The collected data were submitted to analysis of variance and regression and the comparison between sources by 5% Tukey test, SAEG 8.0 (1999).

RESULTS

By the spectrometry method of determination of ammonia volatilization there was no significant difference between urea, urea plus, super N and Yarabela[®] in the first and fourth collection as shown in Table 2. The urea ammonium sulfate, urea plus, super N and Yarabela[®] presented an increase in the fourth collection and then dropped in the N-NH₃ content, this may be due to temperature oscillation during the collection period, because the temperature during the experiment oscillated with periods of cold days (16°C) and high temperatures (40°C). In the second and fifth day there was no significant difference between urea, urea plus, the same occurred between the ammonium sulfate and yarabela who had the lower volatilization. This result can be explained by the presence of S in the ammonium sulfate and in the Yarabela[®] source.

Lara Cabezas et al. (2005) and Lara Cabezas and Couto (2007) found that ammonium sulfate in relation

to urea gave a higher yield of maize, the authors attributed to the cause of the observed response, S present in the ammonium. By ribbon distillation methodology, there was no significant difference in volatilization in the 1st, 2nd and 7th gathering; in the 3rd, 4th and 5th collects the ammonium sulfate and Yarabela[®] showed similar behavior to that presented in the distillation of foam and the spectrophotometer not differing statistically from each other with the least amount of evaporation.

Manzoni and Trivelin (2003) when comparing absorbed paper to the method of ¹⁵N balance, observed that paper absorbs only estimated actual losses of NH₃ by volatilization in high volatilization conditions. On the fifth day, urea plus had the highest N-NH₃ volatilized content differing from the other treatments in the distillation method of tape and foam. In the distillation of the foam there was no significant difference between urea, urea plus and Yara bela[®] on the first day, result that was also observed by the spectrophotometry method. The results found in the second collection by spectrophotometry and distillation of the foam are similar, there was no significant difference between super N ammonium sulfate and Yarabela[®]. The volatilization of urea and urea plus did not differ statistically and the super N volatilization was similar to urea plus in the seventh day. In the tenth collection, super N volatilization showed a content of N-NH₃ higher than others. In the 14th gathering there was no significant difference between the N-NH₃ levels for urea, urea plus and super N when measured by the distillation of tape and foam.

By the foam distillation in the 18th collection, volatilization of Super N was similar to urea, a result also found by spectrophotometry among the ammonium sulfate and Yarabela[®] there was only significant difference in the spectrophotometry method, where the ammonium sulfate showed high N-NH₃ content in the first day, in the seventh day and in the 14th day, a result similar to that was found in foam distillation on the first day. The ammonium sulfate and Yarabela[®] in both methodologies had the lowest N-NH₃ volatilized values. The length showed a significant difference in the collector tape system and the treatment with super N was superior to the others (Table 3). The nitrogen content did not differ statistically in the collecting system of N-NH₃ by the foam distillation, but in the evaluation of the tape distillation system, the leaf nitrogen content in the treatment with Yarabela[®] was lower than the other treatments. There was a positive correlation between capture systems of volatilized ammonia as shown by correlation analysis presented in Table 4, however, in the methods of determining the volatilized nitrogen, the assessment made by the spectrophotometer detected low levels of nitrogen compared to the distillation method.

DISCUSSION

Tasca et al. (2011) says that the greatest NH₃ losses

Table 2. Ammonia volatilization in function of days after the application of fertilizers, assessed by different collectors and methods of N determination.

Fertilizers	Collection (days)						
	1	2	5	7	10	14	18
Collector Tape- Spectrophotometer (g kg⁻¹)							
Urea	0.06 ^b	7.8 ^a	10.44 ^a	4.18 ^a	7.97 ^a	2.77 ^b	2.17 ^a
Urea plus	0.04 ^b	8.28 ^a	14.88 ^a	4.1 ^a	6.77 ^{ab}	2.35 ^b	1.94 ^{ab}
Super N	0.03 ^b	1.48 ^b	9.66 ^{ab}	4.1 ^a	3.75 ^{bc}	4.26 ^a	1.65 ^{ab}
Ammonium S.	0.65 ^a	0.09 ^b	0.19 ^b	0.23 ^b	0.07 ^c	0.07 ^c	0.09 ^b
Yarabela [®]	0.08 ^b	0.06 ^b	0.12 ^b	0.1 ^b	0.23 ^c	0.03 ^c	0.04 ^b
F Values	114.9**	10.38**	9.5**	16.78**	17.08**	37.094**	5.17*
CV (%)	28.62	72.69	60.76	41.66	46.8	31.09	77.11
Collector tape-distillation (g kg⁻¹)							
Urea	1.08	4.4	86.76 ^b	43.56 ^A	53.5 ^a	29.41 ^a	2.76
Urea plus	0.96	5.97	96.82 ^a	28.67 ^A	5.42 ^b	35.39 ^a	2.82
Super N	0.71	5.23	9.97 ^c	35.76 ^A	4.37 ^b	6.16 ^b	2.23
Ammonium S.	0.65	3.34	2.42 ^d	4.68 ^B	2.66 ^b	3.13 ^b	2.11
Yarabela [®]	0.93	2.54	1.66 ^d	3.59 ^B	1.92 ^b	2.89 ^b	1.98
F Values	0.3 ^{ns}	1.67 ^{ns}	11.14**	27.4	9.92**	40.83	0.18 ^{ns}
CV (%)	76.04	49.91	7.27	29.96	104.6	31.96	23.52
Collector foam-distillation (g kg⁻¹)							
Urea	0.56 ^b	50.35 ^a	14.56 ^a	63.74 ^A	14.35 ^b	35.26 ^a	25.03 ^a
Urea plus	0.31 ^b	55.01 ^a	17.35 ^a	63.07 ^{Ab}	12.01 ^b	30.36 ^a	2.69 ^b
Super N	0.09 ^b	9.2 ^b	20.95 ^a	41.71 ^B	22.92 ^a	4.67 ^b	25.1 ^a
Ammonium S.	2.35 ^a	0.56 ^b	0.72 ^b	1.09 ^C	0.71 ^c	0.92 ^b	0.46 ^b
Yarabela [®]	0.55 ^b	0.64 ^b	0.83 ^b	0.29 ^C	0.53 ^c	0.28 ^b	0.47 ^b
F Values	26.55**	45.54**	32.09**	43.93**	52.37**	15.02**	13.41**
CV (%)	45.6	34.86	30.83	28.11	26.16	61.61	66.58

Means followed by the same letter in the column do not differ by Tukey test at 5%.

occurred proportionally with the increase in temperature. In an experiment conducted in the laboratory, it was observed that when urea was put in a surface at a temperature of 18°C there was a reduction of 4.6 times lower than when put at 35°C. In wet soils, near field capacity, the gaseous ammonia losses accompany the process of evaporation of water.

Silva and Vale (2000) in nitrate availability in Brazilian soils under the influence of liming and sources and doses of nitrogen explains that cause elevation of pH around the granule which slows volatilization of ammonia. The volatilization of urea, urea plus, super N did not differ statistically from each other on the second day. Trivelin (2001), the methods with chambers are relatively simple and suitable for an experiment with small amount and various treatments in the same area. One of the disadvantages of this system is the formation of microclimate with the modification of the environmental conditions inside as intensity, light wavelength, temperature, relative humidity, ventilation and the

formation of dew, which certainly influence the volatilization of NH₃ when compared to natural conditions (Table 2).

For the variables dry matter and plant height shown in Table 3, there was no significant difference for the different methods of determination of N-NH₃ volatilization. Regarding the diameter, the ammonium sulfate showed significant difference with larger diameter compared with other sources in determining the collector. This fact can be explained by Koprivova et al. (2000) who reported the importance of the N and S metabolism that are directly related. The assimilation of N and S are well coordinated and the deficiency of one of them can affect the assimilation of the other.

Conclusion

Urea showed the highest loss by volatilization by both evaluation methods: spectrophotometry and distillation

Table 3. Leaf dry matter production, diameter, height, length, leaf N of corn by collector system with the use of filter paper tape and polyurethane foam.

Fertilizer	Leaf dry matter (g/kg)		Diameter (mm)		Height (cm)		Length (cm)		N leaf (%)	
	Foam	Tape	Foam	Tape	Foam	Tape	Foam	Tape	Foam	Tape
Urea	0.21	0.21	8.2	8.1 ^{ab}	39.63	38.4	65.08	66.63 ^b	2.84	2.67 ^{ab}
Urea plus	0.21	0.21	8.6	9.03 ^{ab}	40.88	42.6	66.25	76.65 ^{ab}	3.08	3.24 ^a
Super N	0.21	0.21	7.4	9.55 ^a	38.88	44.4	58.75	82.85 ^a	3.19	2.89 ^a
Ammonium S.	0.21	0.21	8.4	7.03 ^b	41.83	39.3	71.13	64.35 ^b	2.98	3.04 ^a
Yarabela [®]	0.21	0.21	8.1	7.75 ^{ab}	39	36.9	63.68	64.93 ^b	2.84	1.48 ^b
F Values	0.95 ^{ns}	1.17 ^{ns}	0.44 ^{ns}	4.09 [*]	0.19 ^{ns}	1.8 ^{ns}	0.76 ^{ns}	7.45 ^{**}	0.12 ^{ns}	5.4 [*]
CV (%)	2.9	2.26	15.89	12.01	14.77	11.6	15.83	8.51	29.36	22.42

Means followed by the same letter in the column do not differ by Tukey test at 5%

Table 4. Correlation array between systems of volatilized ammonia and N determination method.

Correlation	FIESP	FIDEST	ESPDEST
FIESP	-	-	-
FIDEST	0.90 ^{**}	-	-
ESPDEST	0.94 ^{**}	0.90 ^{**}	-

** Correlation significant at a level of 1% probability by T test. FIESP: tape by spectrophotometry; FIDEST: tape by distillation ESPDEST: foam by distillation.

dragging vapors. The nitrogen content in the leaf tissue by the collector-tape determination in the treatment with Yarabela[®] was lower than the other treatments. The ammonium sulfate and Yarabela[®] in both methodologies had the lowest N-NH₃ volatilized values. The spectrophotometer detected low levels of nitrogen compared to the distillation method.

Conflict of interests

The authors have not declared any conflict of interests.

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