Monitoring of burden gases emission levels after farmyard manure application in grapevine and vegetable growing

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Abstract: Ammonia and greenhouse gas emissions released during the application of farmyard manure in the crop production belong to the most significant air pollution resources of the agricultural activity. In this paper, the results are described of the emissions measurements in different ways of farmyard manure application in grapevine and vegetable growing. On the basis of the emissions measured, optimum procedures of the farmyard manure application were suggested with regard to the burden of environment by the monitored gases as low as possible. Also presented are the system and methodology of measuring the burden gases coming from soil by means of measuring chambers.

Keywords: ammonia; greenhouse gases; burden gases emissions; grapevine; head cabbage

The greenhouse and other burden gases emissions (e.g. ammonia) coming from the agricultural activity negatively influence the environmental quality. These gases arise in stables during livestock breeding, storage of and handling with farmyard manure, and mainly as the result of its application into the soil. The farmyard manure application causes relative low gases concentrations but these are emitted from large surfaces. The resulting emissions of burden gases are therefore very important (Nemešová & Pretel 1998).

The Kyoto protocol obliged the Czech Republic to reduce the greenhouse gases emissions by 8%. Similarly, the Goeteborg protocol obliged the Czech Republic to reduce the ammonia emissions coming from the agricultural activity by up to 40%.

The absolute majority of the papers published deal with the emissions measurements generating in the livestock breeding. The methodology of these measurements is now consolidated and most authors perform their measurements using similar procedures. Thus, the published results from this sphere are easily comparable. As regards the measuring of emissions from soil, various methodologies are applied depending on the measuring method utilised (Aneja *et al.* 1995). Authors mostly utilise modified methods with the use of measuring chambers (Anderson & Levine 1987; Roelle & Aneja 2001). The investigated variants of the farmyard manure application use available mechanisation for the manure placement originally determined for vegetable growing (Zemánek 1997). In the experiments carried out and described below, doses were chosen of the selected manure types so as to secure always the same amount of the nitrogenous substances in each experimentall variant (Hlušek 1996; Richter & Hlušek 1999).

METHODOLOGY AND MATERIALS

The scope of the experiment is the monitoring of the greenhouse gases emission levels in horticultural crops growing. The monitoring will be divided into two parts. The most greenhouse gases emission measurements will be performed after the standard methods used for the farmyard manure, green manure, and stabilised compost placement into soil in grapevine growing performed under different soil conditions. The aim of these measurements will be to determine optimum working fertilisation procedures with respect to the burden gases emissions as low as possible while the same grape yields are achieved. The second group of measurements will be carried out at the trial field with identical soil properties, divided into 10 equal plots. Each plot will be fertilised with different organic fertiliser. The se-

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lected fertilisers will be treated with biotechnological agents for the burden gases emissions reduction. All the plots will be seeded with the same crop (white head cabbage) and the yields of the individual plots will be monitored.

The greenhouse gases emission measurements can be provided in different ways. One of them is the utilisation of sorbents and their chemical analysis after the exposition completion. Other possibility is to perform laboratory chemical analysis of gases taken into sampling bags or to use electrochemical or semi-conductor scanners of the individual gases concentrations. After the experience with the utilisation of various methods for the burden gases emission measurement, optimal seems to be the utilisation of an analyser working on the photo acoustics principle. The advantage of this principle is high dynamics of the measuring range, very low detection limits, linearity, and long-time analyser stability as compared with the analysers operating with classical infra-passive method. For the measuring, the gas analyser 1312 A Photoacoustic Multi-gas Monitor will be used manufactured by the Danish firm INNOVA Air Tech Instruments. Its advantage is the possibility to measure the concentrations of up to 5 different gases and water vapour as well as the light sampling speed. The analyser is compact with the construction enabling the measuring in terrain and will be fitted with the optical filters for ammonia, CO_2, methane, H_2S, and water vapour measuring. The analyser will be completed with a switcher 1309 D Multipoint Sampler at the withdrawal points of the same manufacturer enabling to use the analyser for measuring at 12 withdrawal points. The whole set will be controlled by a notebook equipped with a program providing sampling and measured data storage. The apparatus convert automatically the measured concentration to standard conditions (temperature 0°C, pressure 101.3 kPa, dry air). For the soil emissions measuring with the gas analyser, the measuring chambers with opened bottoms will be used. This measurement is performed either by the method of monitoring the concentration speed increase in the closed chamber over the measured surface, or by the determination of the gases mass flow by means of the measuring chamber with defined speed of air forced flow over the measured surface. The first method utilises the gas feature, i.e. its diffusion into the space with a lower concentration (Brown's motion), i.e. the space of the measuring chamber located over the monitored surface to reach equal concentration within the whole volume considered. From the gas concentration time course in the chamber, the time constant can be determined of the concentration increase allowing specification of the monitored gas emissions. For the measurements described, the second method will be used utilising the measuring chamber with forced air constant flow rate over the monitored surface. That method corresponds with the realistic conditions, i.e. the atmospheric airflows over the surface. The measuring chambers with opened bottoms have the following dimensions: base 370 × 560 mm, height 230 mm. The shorter side of the chamber is fitted with suckling holes and on the opposite wall of all chambers are situated the withdrawal ventilators fitted with a socket of the diameter of 75 mm and the length of 300 mm. From the socket, air will be withdrawn via probes to the analyser. The airflow speed in the socket is 1.2 m/s. This corresponds with the speed of the airflow over the measured surface, i.e. about 60 mm/s. The chambers will be fitted with sheet collars providing sufficient chamber sealing over the monitored surface. At the same time, NH_3, CO_2, CH_4, and either N_20 or H_2S will be measured. The temperature, pressure, and air relative humidity will be measured and registered by the apparatus COMMETER D 4141.

RESULTS AND DISCUSSION

Comparison of burden gases emissions in various methods of farmyard manure application in grapevine growing

The burden gases emission measurements were carried out in autumn 2005 in the Southern Moravia region. Two variants of the farmyard manure were chosen:

Variant 1. Manure application in the dose of 40 to 50 t/ha by the spreader POTTINGER 3 (3.0 t) into the inter-row width. The fertilised belt width maintenance was secured by means of two-side diaphragm (sheet plates). The dose adjustment in the spreader was 50 t/ha at the travel speed of 4.5 km/h. The manure dose placement was performed by means of disc harrows into the depth of 0.12–0.15 m.

Variant 2. Manure or compost were applied in the inter-row into the beforehand prepared two-furrow. The furrow axis distance ranged from 1.5 to 1.8 (2.0) m. Together with the furrow ploughing, the considered amount of soil was simultaneously ploughed to the wine shrub heel.

The manure was applied by means of the spreader POTTINGER 3 (3.0 t) passing through the ploughed furrows (travelling speed 4.0 km/h). After that, the manure plough down followed by means of the plough with two blades on the cultivator frame.

Site Žabčice. The measurement was carried out on 19 October 2005 from 9:20 a.m. to 11:20 a.m. Two chambers in the inter-row were placed at the trial field with manure applied by the spreader 5 days before the measurements and its consequent placement with the disc harrows into the depth of 0.15 m in the dose of 4 kg/m^2, and two chambers in the furrow at the root system with manure applied by plough down into the dept of 0.25 m with the blade plough again in the same dose of 4 kg/m^2. Sandy black earth was loose only with slight porosity after the manure application. Air temperature ranged during the measurement from 7.8 to 11.2°C, air relative humidity was from 39.2 to 60.4% and air pressure from 1001.4 to 1002.2 hPa. During the whole measuring time was a calm. The calculated emission flows at the air speed of 6 cm/s over the monitored surface as related to 1 m^2 are presented in Table 1.

Site Valtice. The measurement was carried out on 19 October 2005 from 2:40 p.m. to 4:40 p.m. At the trial field were situated, similarly as in the previous case, two chambers in the inter-row with manure applied by the spreader 5 days before the measurement with its consequent placement with the disc harrows into the depth of 0.15 m in the dose of 4.4 kg/ m^2, and two chambers in the furrow at the root system with manure applied by plough down into the dept of 0.25 m with the blade plough again in the dose of 4.4 kg/ m^2. The sandy black earth on the field created small clods with relative small porosity after the manure application. Air temperature changed during the measurement from 9.0 to 16.3°C, air relative humidity from 36.0 to 58.6% and air pressure from 991.1 to 992.8 hPa. A mild wind was blowing during the measuring time but largely it was calm. The measuring chambers were situated perpendicularly to the wind direction and fitted with improvised windbreaks on the side with the suckling holes. The calculated emission flows at the wind speed of 6.cm/s over the monitored surface (related to the area of 1 m^2) are shown in Table 2.

Site Velké Bílovice. The measurement was performed on 20 October 2005 from 9:40 a.m. to 11:50 a.m. Two chambers in the inter-row were placed at the trial field with manure applied by the spreader 6 days before the measurement and its con-

Table 1. Emission flows of monitored gases at the site Žabčice

Emission flows (g/h)	Inter-row			Root system		
	probe 1	probe 4	average	probe 2	probe 3	average
NH_3	5.34	6.05	5.69	3.38	4.36	3.38
CO_2	684.30	283.11	483.70	284.35	262.60	273.47
CH_4	7.05	4.72	5.88	2.46	2.77	2.61
H_2S	1.75	1.36	1.56	1.39	1.33	1.36

Table 2. Emission flows of monitored gases at the site Valtice

Emission flows (g/h)	Inter-row			Root system		
	probe1	probe 3	average	probe 2	probe 4	average
NH_3	6.31	10.01	8.16	4.46	7.28	5.87
CO_2	1086.67	1115.35	1101.01	983.56	943.39	963.47
CH_4	12.38	16.28	14.33	10.33	11.78	11.06
H_2S	1.70	1.72	1.71	2.08	1.72	1.90

Table 3. Emission flows of monitored gases at the site Velké Bílovice

Emission flows (g/h)	Inter-row			Root system		
	probe 1	probe 3	average	probe 2	probe 4	average
NH_3	3.56	2.76	3.16	2.46	4.42	3.44
CO_2	569.56	350.89	460.23	642.07	585.42	613.75
CH_4	5.43	2.68	4.06	2.38	6.28	4.33
H_2S	1.80	1.19	1.49	1.33	1.04	1.18

sequent placement with the disc harrows into depth of 0.10 m in the dose of 5 kg/m^2, and two chambers in the furrow at the root system with manure applied by plough down into the depth of 0.25 m (blade plough) in the same dose of 5 kg/m^2. Clay black earth created big clods with large porosity after the manure application. Air temperature changed during the measurement from 9.0 to 16.3°C, air relative humidity ranged from 36.0 to 58.6%, and air pressure from 991.1 to 992.8 hPa. During the whole measuring time was a calm. The calculated emission flows at the air speed of 6 cm/s over the monitored surface related to 1 m^2 are presented in Table 3.

The percent emissions comparison related to 1 m^2 with the utilisation of both technologies in all the localities measured is presented in Table 4.

The monitoring of the utilised technology effect during the grapevine growing revealed that the emission flows of all gases were lower when manure was ploughed down to the root system in comparison with the application into the inter-row and consequent placement with disc harrows at the sites in Žabčice and Valtice. This was caused by a deeper placement by plough down to the root system and a smaller area of the manure application. At the site Velké Bílovice, the emission flow during manure plough down to the root system was more intensive in comparison with the application in the inter-row. This was caused after the plough down by big clods and porosity. The ploughed down gases then can leak to the surface through the gaps between the clods.

Table 4. Percent comparison of burden gases emissions flows with utilisation of two technologies at all sites

Emission flows	Inter-row	Root system
Site Žabčice		
NH_3 (%)	100	59
CO_2 (%)	100	57
CH_4 (%)	100	44
H_2S (%)	100	87
Site Valtice		
NH_3 (%)	100	72
CO_2 (%)	100	88
CH_4 (%)	100	74
H_2S (%)	100	111
Site Velké Bílovice		
NH_3 (%)	100	109
CO_2 (%)	100	133
CH_4 (%)	100	107
H_2S (%)	100	79

The area of the manure application in the inter-row (the width of the inter-row is at least 2.2 m) is significantly larger than that in the application of manure to the root system. In this case, the furrow width is about 30 cm from each side of the inter-row. Therefore, the inter-row area is at least 3.7 times larger than that with manure applied to the root system by plough down. From this resulted that unambiguously more advantageous for the burden gases emissions reduction is the technology of manure plough down to the root system than the application in the inter-row with consequent placement performed with the disc harrows.

Field experiment focused on the investigation of various farmyard manures effects on ammonia and greenhouse gases emissions in comparison with the horticultural crops yields

The scope of the experiment was to compare ammonia and greenhouse gases emissions in different variants of horticultural crops fertilisation. The white cabbage (*Brassica oleracea* L. convar. *capitata* var. *capitata*), the variety Selma, was chosen for this purpose. This crop belongs to the 1st track and is thus tolerant of direct farmyard manure application. It has no high demands on cultivation during the vegetation period. The average vegetation period of cabbage is 120 days.

Trial No. 1 (2005). This trial was established in the field located within the area of the Research Institute of Crop Production (RICP) in Prague-Ruzyně. A field of acreage of 200 m^2 (20.0 × 10.0 m) was divided into 10 plots of the size 2.0 × 10.0 m each. Each plot (20.0 m^2) was fertilised with the selected

Table 5. Plots dislocation on field and abbreviations used for individual fertilisers

Fertiliser	Abbreviation
Poultry litter	DR
Cattle manure + AMALGEROL	HO + AM
Compost	KO
Pig slurry + 2× compost + AMALGEROL	VE + 2KO + AM
Poultry litter + AMALGEROL	DR + AM
Pig slurry + 3× compost	VE + 3KO
Cattle manure	HO
Pig slurry + 2× compost	VE + 2KO
Reference	KONT
Compost + AMALGEROL	KO + AM

Table 6. Average concentrations of monitored gases from individual plots – trial No. 1

Plot	Concentration (mg/m^3)			
	NH_3	CO_2	CH_4	H_2S
DR	16.44	117	9.87	1.283
HO + AM	18.12	75	8.33	1.251
KO	4.23	31	0	1.523
VE + 2KO + AM	10.36	40	0.99	1.657
DR + AM	15.9	42	6.87	3.65
VE + 3KO	6.15	25	2.72	2.055
HO	15.37	106	6.97	1.298
VE + 2KO	8.21	44	1.26	1.672
KONT	2.26	40	1.45	0.776
KO + AM	4.42	28	0	1.591

For abbreviations see Table 5

type of farmyard manure 14 days before seeding. One plot was not fertilised and served as a reference plot. Some plots were treated with the agent Amalgerol during the manure application to reduce ammonia emissions. Table 5 shows the dislocation of the plots and the abbreviations used for individual fertilisers. The fertiliser dose was suggested so as to give all plots equal nitrogen amounts. Fertilisers were applied regularly into the furrows with the pitch of 0.5 m and then the whole area was tilled with rotary harrows.

After the field adaptation, the NH_3, CO_2, CH_4, and H_2S emissions measurements followed using the gas analyser INNOVA 1312 completed with the measuring points switcher INNOVA 1309.

For the air sampling, the measuring chambers with opened bottoms were used, similarly as in the previous trial. The calculated average concentrations of the monitored gases for the selected variants of fertilisation are presented in Table 6. Cabbage was seeded from pre-cultivated seeds on May 12, 2005, in the spacing of 0.5 × 0.5 m. At the end of the vegetation period, the cabbage was harvested on September 10, 2005. The cabbage heads from the individual trial variants were harvested separately and then weighed. The yields of the individual variants are presented in Table 7.

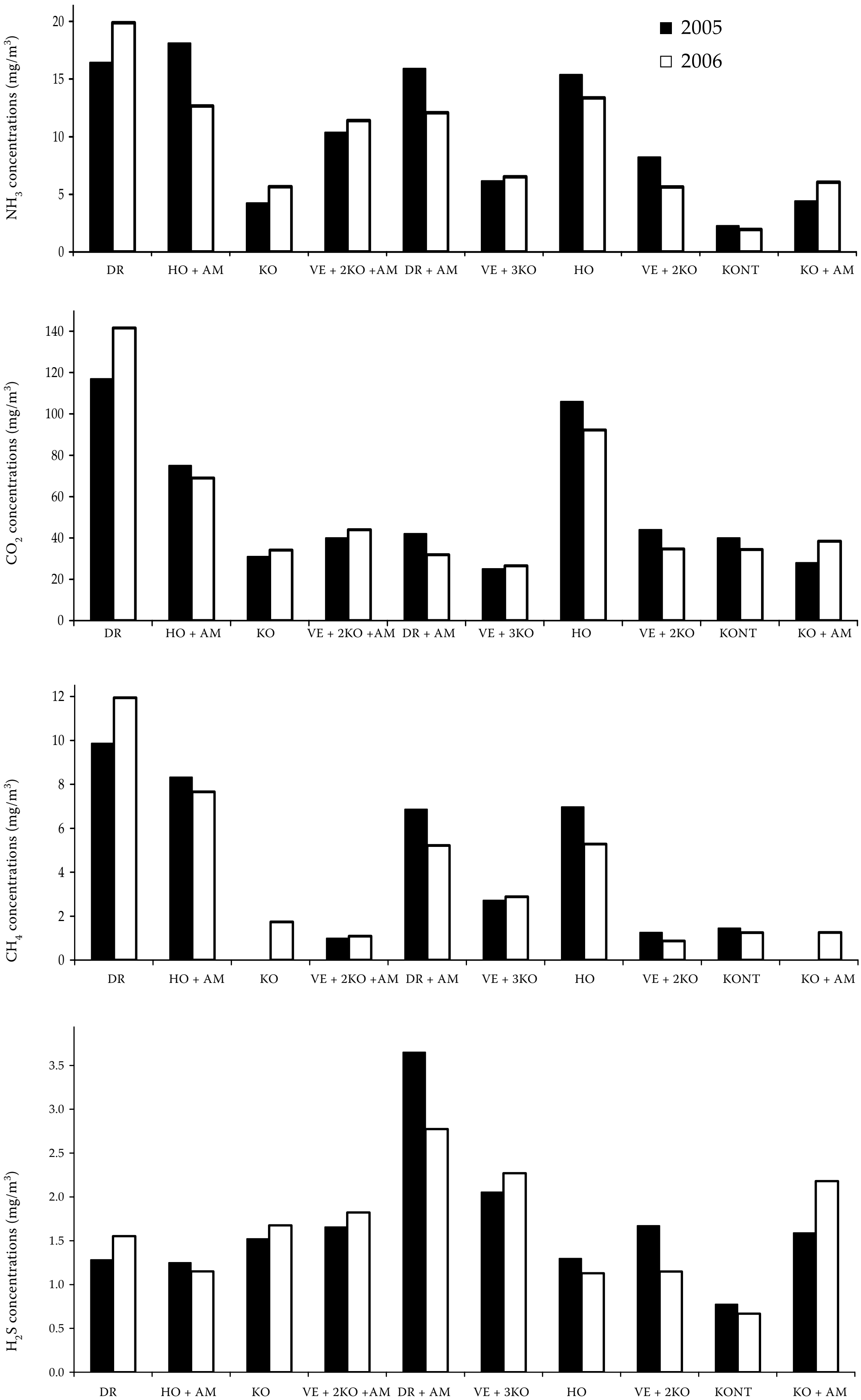
Trial No. 2 (2006). After the cabbage harvest on September 10, 2005 the whole field was ploughed. The same variants and amounts of fertiliser were applied again for the individual plots as in trial No. 1. After the field adaptation with the rotary harrows and harrowing, the emission measurings were carried out by the same procedure as in the previous trial. The calculated average concentrations of the monitored gases for all fertilisation variants in trial No. 2 are presented in Table 8. The average concentrations of the monitored gases found in the individual plots in both trials are illustrated in Figure 1.

On May 10, 2006, the monitored gases concentration measurements were carried out before the cabbage seeding with the same procedure as in 2005. All the concentrations measured in the outflow sockets of the measuring chambers were similar to the monitored gases concentrations in the ambient air environment, the differences between these values being below the analyser resolution ability. Therefore, no measurable emissions of the monitored gases had

Table 7. Cabbage head yields and average weights – trial No. 1

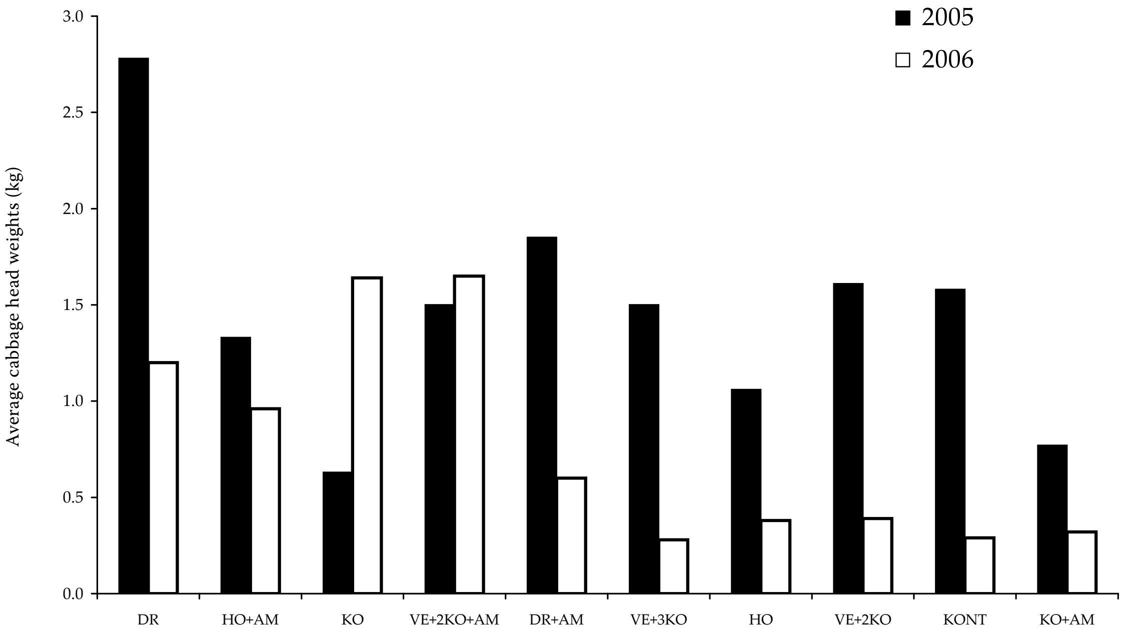
Plot	Yields (kg)	Cabbage head average weight (kg)
DR	111	2.78
HO + AM	61	1.33
KO	30	0.63
VE + 2KO + AM	66	1.5
DR + AM	81	1.85
VE + 3KO	66	1.5
HO	48	1.06
VE + 2KO	64	1.61
KONT	44	1.58
KO + AM	34	0.77

For abbreviations see Table 5



For abbreviations see Table 5

Figure 1. Average NH_3, CO_2, CH_4, and H_2S concentrations – trial No. 1 and 2



For abbreviations see Table 5

Figure 2. Average cabbage head weights – trial No. 1 and 2

leaked from the soil in the individual plots. On May 18, 2006, the cabbage seeding was performed with the procedure same as in the previous year. On October 18, 2006, cabbage was harvested using the same procedure as in the previous trial. The yields and cabbage head average weights achieved with the individual plots are presented in Table 9. Graphical illustration of the cabbage head average weights from the plots with different fertilisation variants in both trials is presented in Figure 2.

Out of the ammonia concentrations measured, the highest values were achieved with poultry and cattle manure application. The highest effect on the emissions reduction was achieved with the Amalgerol agent in the application of poultry manure. A significantly lower yield was obtained in trial No. 2 with almost all fertilisation methods as compared with the trial No. 1. Evidence was obtained for nitrogen losses caused by ammonia gaseous emissions during the long period from the autumn application to the later spring seeding in the next year. The highest efficiency in the trial No. 2 was achieved with the compost utilisation. Nitrogenous substances in it are well bound for a long time in comparison with the farmyard manure.

Table 8. Average concentrations of monitored gases from individual plots – trial No. 2

Plot	Concentration (mg/m^3)			
	NH_3	CO_2	CH_4	H_2S
DR	19.89	141.57	11.94	1.55
HO + AM	12.67	69.00	7.66	1.15
KO	5.65	34.10	1.74	1.68
VE + 2KO + AM	11.40	44.00	1.09	1.82
DR + AM	12.08	31.92	5.22	2.77
VE + 3KO	6.52	26.50	2.88	2.27
HO	13.37	92.22	5.28	1.13
VE + 2KO	5.64	34.72	0.87	1.15
KONT	1.94	34.40	1.25	0.67
KO + AM	6.06	38.36	1.26	2.18

For abbreviations see Table 5

Table 9. Cabbage heads yields and average weights – trial No. 2

Plot	Yield (kg)	Cabbage head average weight (kg)
DR	89	1.2
HO + M	70	0.96
KO	133	1.64
VE + 2KO + AM	128	1.65
DR + AM	45	0.6
VE + 3KO	24	0.28
HO	23	0.38
VE + 2KO	23	0.39
KONT	21	0.29
KO + AM	19	0.32

For abbreviations see Table 5

During the cabbage seeding immediately after the fertilisers application (trial No. 1), the highest yield was achieved with the poultry manure application. In this case, the nitrogenous substances are released quickly which is confirmed also by the highest ammonia concentrations in both measurements.

As manure is applied immediately before the cabbage seeding, the highest average cabbage head weights will be achieved with the poultry manure application. With the spacing of 0.5 × 0.5 m, the yield of about 111 tons per hectare is achieved. The ammonia emissions will be high at the beginning but will be considerably reduced in the course of the vegetation period.

At the soil cultivation in autumn and spring seeding, the variant using fertilisation with compost seems to be optimum as confirmed by the measurement. The nitrogenous substances are released from the soil in the form of ammonia emissions on the lowest scale and the yield is about 66 tons per hectare. The ammonia emissions will thus be the lowest of all the variants monitored.

CONCLUSIONS

From the comparison of the burden gases emissions, it is evident that, after the farmyard manure application into furrow, the resulting emissions per surface unit are significantly lower as compared with the most frequently utilised manure spreading into the inter-row and its consequent placement with the disc harrows. This is caused by the deeper placement in ploughing down to the root system and by a smaller surface for the manure application.

For agriculture, one of the largest global producers of greenhouse gases, it will be necessary in future to find new, available cultivation technologies allowing to reduce the greenhouse gases emissions to acceptable limits.

Generally, the deficit of organic matter in soil is ever higher even in the permanent vegetation. This can lead to the biological activity limitation in soil and the deterioration of its fertility. Regarding the organic matter role in soil, experiments have proved that a suitable application of mechanisation can ensure the crops nutrition and, at the same time, reduce the emission burden. It must be noticed that the emissions levels affect considerably the soil type and structure as well as the time between the organic manure applications, its placement, and emissions evaluation. The future solution of the problem should be aimed at the compost utilisation applicable by suitable mechanisation for the grapevine growing, and generally in horticulture directly to the root system. This procedure provides minimum emission burden from the soil. The possible solution could be for example machines on the basis of deep tillers with the application of fine compost to the furrow bottom, machines for the "nest" compost application to the root zone, spreaders with side rectification, the exploitation of spade ploughs for compost placement etc.

The utilisation of these results in agricultural practice is connected with many technical and economical problems. First, it is the question of available technical equipment for the application of organic manure into the furrow. Practice utilises mostly the organic manure broad application into the inter-row due to its simplicity requiring only a single machine passing through. The market now offers a wide choice of the organic manure and compost spreaders for various inter-row widths. The application into the furrows is thus at present used only onto small surfaces with a high share of manual work with the support of small mechanisation. It results from the beforehand presentation that fertilisation into the furrow also means cost increases which may be not compensated by the emissions reduction.

It connection with the results of the emission measuring in different fertilisation variants for white cabbage growing, models were suggested leading to the emissions reduction maintaining at least the same yield.

References

Anderson I.C., Levine J.S. (1987): Simultaneous field measurements of biogenic emissions of nitric oxide and nitrous oxide. Journal of Geophysical Research, **92**: 965–976.

Aneja V.P., Robarge W.P., Hollbrook B.D. (1995): Measurements of nitric oxide flux from an upper coastal plain, North Carolina agricultural soil. Atmospheric Environment, **21**: 3037–3042.

Hlušek J. (1996): Základy výživy a hnojení zeleniny a ovocných kultur. Institut výchovy a vzdělávání ministerstva zemědělství ČR v Praze, Praha.

Nemešová I., Pretel J. (1998): Skleníkový efekt a životní prostředí. Ministerstvo životního prostředí ČR, ČHMÚ, ÚFA AV ČR, Praha.

Richter R., Hlušek J. (1999): Výživa a hnojení rostlin. 1st Ed. MZLU v Brně.

Roelle P.A., Aneja V.P. (2001): Nitric Oxide Emissions From Soils Amended with Municipal Waste Biosolids. Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh.

Zemánek P. (1997): Návrh expertního systému pro využití mechanizačních prostředků ve vinohradnictví. [Disertační práce.] MZLU v Brně, Zahradnická fakulta v Lednici na Moravě.

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Abstrakt

Češpiva M., Burg P. (2007): **Sledování úrovně emisí zátěžových plynů po aplikaci statkových hnojiv při pěstování révy vinné a v zelinářství**. Res. Agr. Eng., **53**: 134–142.

Emise amoniaku a skleníkových plynů uvolňovaných při aplikaci statkových hnojiv v rostlinné výrobě patří díky velkým plochám k nejvýznamnějším zdrojům znečištění ovzduší zemědělskou činností. Jsou popsány výsledky měření emisí při různých způsobech aplikace statkových hnojiv při pěstování révy vinné a při použití různých statkových hnojiv, které lze využít při pěstování zelenin. Na základě naměřených emisí byly navrženy optimální postupy aplikace statkových hnojiv s ohledem na co nejnižší zatěžování životního prostředí sledovanými plyny. Je uveden systém a metodika měření emisí zátěžových plynů z půdy pomocí měřicích komor.

Klíčová slova: amoniak; skleníkové plyny; emise zátěžových plynů; vinná réva; zelí hlávkové

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