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Technological and economic evaluation of manure production using an activator of biological transformation

Petr Šařec[1]*, Oldřich Látal[2], Petr Novák[3]

[1]*Department of Machinery Utilization, Faculty of Engineering, Czech University of Life Sciences Prague, Prague, Czech Republic*
[2]*Agrovýzkum Rapotín, Vikýřovice, Czech Republic*
[3]*Department of Agricultural Machines, Faculty of Engineering, Czech University of Life Sciences Prague, Prague, Czech Republic*

**Corresponding author: psarec@tf.czu.cz*

Abstract

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The aim of this paper was to verify the effect of the Z'fix (PRP Technologies, France) activator of biological transformation of manure from the viewpoint of the cowshed conditions parameters, produced manure quality, manure application effect on crop yields, and overall economics. Concerning manure production, the application of the Z'fix agent enhanced quality, structure and nutrient content (N total by 23%, P_2O_5 by 42%, K_2O by 17%) in the manure from deep litter housing. Compared to the untreated control, differences in the nutrient content of N total and K_2O were statistically significant, NH_3 emissions dropped significantly by almost 35%. The economic benefit of manure production with the use of the Z'fix agent demonstrated overall savings at the level of 1,369 CZK/LU/year. The influence of manure produced combined with the PRP Sol application was tested in terms of a boost of crop yield potential of silage maize and of winter wheat. Compared to the control, both crops reached yields higher by 0.7% to 9.8%.

Keywords: Z'fix; PRP Sol; deep litter; ammonia emission; economy; yield; winter wheat; silage maize

Appropriate quality and sufficient quantity of farmyard manure produced in cattle breeding are essential prerequisites to ensure adequate soil fertility. Soil solid phase contains on average 2–5% of organic matter, of which substantial part is not humified. This part mineralizes in soil and represents major nutrient storage for plants. In the conditions of the Czech Republic, annual consumption of such organic substances ranges between 4.0 to 4.5 t/ha (Škarpa 2014). This amount is covered from 2.0 to 2.5 t/ha by the crop residues, and the remaining ca. 2 t/ha are necessary to be supplied by organic fertilizers. Recently, the application of organic fertilizers, e.g. farmyard manure, slurry or liquid dung, has varied only between 0.6 and 0.7 t/ha (Richter et al. 2002). From a long-term point of view, the balance of organic substances is negative in soil, i.e. number of cattle bred in the Czech Republic does not amount to a level ensuring sufficient production of high-quality farmyard manure. Its production dropped from 26.2 million of tons in 1985 to mere 10.9 million in 2005 (Klír et al. 2008). Samuil et al. (2009) concluded that the application of organic matter of the farmyard manure origin has a positive influence on the physical, chemical and biological parameters of soil and on its fertility.

One of the ways of enhancing soil characteristics is to boost the production of the superior quality farmyard manure with the employment of agents on the basis of activators of biological transformation of organic matter. One of such agents is Z'fix (PRP Technologies, France) that should improve

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the parameters of cowshed conditions, farmyard manure quality, fermentation process optimization and ammonia production. Incorrect fermentation process and straw bedding of low quality are the main causes of higher microbiological contamination and ammonia production, lower urine absorption ability and finally higher labour requirements and costs for a breeder. Jelínek et al. (2004) and Brouček et al. (2014) focused on testing of such agents.

In order to decrease acidification and eutrophication, the Gothenburg Protocol sets levels to reduce ammonia emissions in livestock housing systems by at least 20%. Straw (litter) quality and its amount play an important role in farmyard manure production. An optimal amount of straw and its treatment is very important in terms of manure manipulation, liquid manure absorption ability in the barn, animal welfare, optimal microbial activity during the fermentation (optimal temperature and ammonia emission production), and of the total cost per a feeding day. In the Czech Republic, a mean amount of straw in the straw bedding ranges between 7.0–11.0 kg/LU/day (livestock unit, 1 LU = 500 kg of life weight). Gilhespy et al. (2009) tested the optimal amount of straw in bedding with regard to ammonia emission production within beef cattle breeding. They found, that the quantity of 4.7 kg/LU/day had a positive effect, i.e. a decrease in ammonia emission by 50%, but the difference was not significant.

The objective of this paper was to verify efficiency of the Z'fix agent from the viewpoint of the cowshed conditions parameters including ammonia emissions, produced manure quality, manure application effect on crop stand and crop yields, and overall economics.

MATERIAL AND METHODS

In order to verify the effect of the Z'fix (PRP Technologies, France) agent on technological and economic parameters of housing as well as on crop yield and on overall economy, an experiment was established in Lázně Bělohrad in the North Bohemia Region in the year 2014. The experiment can be divided into two stages. The first one was focused on manure production in deep litter housing where Z'fix served as an activator of the biological transformation of manure. The second stage consisted of a field trial that tested the impact of manure and the Z'fix agent on crop stand and crop yields. Variants of the field trial were extended by additional application of PRP sol (PRP Technologies), which is an activator of biological transformation in soil.

First stage – manure production. There were two cowsheds with a loose box and deep litter housing, each containing on average 60 livestock units (1 LU = 500 kg) of dairy cows.

In the first cowshed with the housing area of 540 m^2 (control variant), the removal of fresh dung was done in 3–4 weeks intervals according to the condition of bedding, and spreading of straw was accomplished 3 times a week.

In the second cowshed with Z'fix used and with the housing area of 520 m^2 (treated variant), the removal of fresh dung was done in 6 – 8 week-intervals according to the condition of bedding, and spreading of straw and Z'fix application was accomplished 3 times a week. Z'fix is a pellet formed by a matrix of calcium and magnesium carbonate with an active mixture of specific mineral salts that should help control fermentation in liquid or solid organic substances. A weekly dose of Z'fix was set at 0.7 kg per one livestock unit with respect to body weight of cows. After the removal from cowsheds and prior to the application in the experimental field, the manure stayed in separate dung hills for approximately two months.

The samples of stall dung or manure were taken continuously two times a month from the cowsheds and once a month from the dung hills. The samples were analysed straightway in the certified laboratory of Agrovýzkumu Rapotín s.r.o. At five locations in each cowshed, temperature of bedding (measurement range 0–200°C ± 0.1°C) and emissions of NH_3 (measurement range 0–100 ppm ± 0.1 ppm) at 0.25 m above the bedding surface were measured for the period of one hour every time the above mentioned samples were taken. The emissions were measured using the Data Logger NH_3 (Bauer GmbH, Germany) that operated based on a chemical reaction. The emission measurements should be considered as indicative only. The sides of cowsheds were of opened construction, thus making it difficult to determine the air flow.

The following parameters were thus measured and monitored:

manure: N_{tot}, $N\text{-}NH_4^+$, P, K, Ca, Mg, S, pH;

cowshed: NH_3 emissions (0.25 m above bedding surface), temperature of bedding;

other parameters: overall manure production (tons per cowshed), overall straw consumption (tons

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Table 1. Averages of chemical analysis of manure samples treated with Z'fix and of control manure samples, and averages of ammonia emissions and maximum bedding temperatures (8/2014 to 11/2016)

	Manure treated with Z'fix	Control – untreated manure	Index	*P*
No. of samples	120	125	–	–
Dry matter (%)	23.6	23.1	–	–
N total (kg/t)	6.90	5.63	1.23	0.0294
$N\text{-}NH_4^+$ (%)	0.43	0.32	1.34	–
P_2O_5 (kg/t)	4.10	3.70	1.42	0.0563
K_2O (kg/t)	8.10	6.90	1.17	0.0479
C:N	18.1:1	22.3:1	0.82	–
NH_3 (ppm)	15.20	23.38	0.65	0.0223
T max (°C)	27.00–29.00	43.00–46.00	–	–

per cowshed), quantity and frequency of fresh dung removal (No. per cowshed), Z'fix agent consumption (tons per cowshed).

Final economic evaluation of the two differing treatments of the manure production was based on the certified methodology of Látal et al. (2015).

Second stage – field trial. In the second stage of the experiment, a field trial was established at the agricultural company ZEPO Bělohrad a.s. where the influence of manure produced in the first stage combined with PRP Sol application was tested, primarily in terms of boost of crop yield potential (2015 – silage maize, 2015/16 – winter wheat), from a long-term viewpoint in terms of possible amelioration of overall soil fertility and soil organic matter formation.

The trial field (GPS coordinates 50°27.253'N, 15°34.208'E) was located near Lázně Bělohrad in the North Bohemia Region and started in 2014 after the wheat harvest. The topography was gently sloping, facing south-west, at the altitude of 410 m. In October of 2014, soil samples were taken in order to determine chemical and physical parameters. Soil type was *Modal Luvisol*, and soil texture was silt loam. At the depth of 0–0.3 m, soil bulk density was 1.51 g/cm^3, the content of particles under 0.01 mm was 30% of weight, humus content was 1.81%, total porosity was 41.97%, pH (H_2O) was 6.26, and the cation exchange capacity was 110 mmol/kg.

The trial variants differed only in the manure used (untreated vs treated with Z'fix) and in the application of PRP Sol that served as an activator of biological transformation of soil:

I – untreated manure,
II – untreated manure and PRP Sol activator,
III – manure treated with Z'fix),
IV – manure treated with Z'fix and PRP Sol activator.

PRP sol is a granulate containing 32% of CaO and 8% of MgO, which means that it is a calcium fertilizer with magnesium added, and also containing 3.5% of sodium (Na) and 3–5% of prefixes with 48 trace elements that should boost the biological activity of the soil by stimulating soil microflora and its enzyme activity. It can be used for all crops grown in the conventional and organic farming

Table 2. Development of average annual farm prices of fertilizers and nutrients

Fertilizer	2014	2015	2016
Fertilizer costs (CZK/t)			
Ammonium nitrate with chalk (27% N)	6,634	7,011	5,776
Ammophos (12% N, 52% P_2O_5)	11,849	13,287	12,066
Manure salt 60% granulated (60% K_2O)	9,509	9,412	8,945
Recalculated nutrient costs (CZK/kg)			
Ammonium nitrate with chalk (27% N)	24.57	25.97	21.39
Ammophos (12% N, 52% P_2O_5)	17.12	19.56	18.27
Manure salt 60% granulated (60 % K_2O)	15.85	15.69	14.91

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Table 3. Costs of nutrients contained in cattle manure including straw over the period of 2014–2016

Organic fertilizer	Dry matter (%)	2014 (CZK/t)	2015 (CZK/t)	2016 (CZK/t)	2014–2016 (CZK/t)
Cattle manure – legislative	22.0	530	548	506	528
Cattle manure – Z'fix treated	23.6	558	577	533	556
Cattle manure – control	23.1	490	506	470	489
Cereal straw	85.0	1,006	1,016	981	1,001

systems, where the annual doses range between 150–300 kg/ha.

The trial plot was a 120 m wide and 400 m long rectangle selected to be homogenous and to avoid headland. It was divided lengthwise into four individual 400 m long and 30 m wide subplots. The trial field was worked using standard agronomical technology in place. In the year 2014, winter wheat was an advance crop. Crop rotation was alike within all the variants. In 2015, silage maize was grown, in 2015/16 it was winter wheat. Manure application according to the variant was carried out at the rate of 50 t/ha in the autumn of 2014. Manure was ploughed down within two hours after the application by medium-depth ploughing. PRP Sol was applied according to the variant two times in 2015 prior to sowing of maize and of winter wheat, both times at the rate of 200 kg/ha using a common fertilizer spreader.

RESULTS AND DISCUSSION

First stage – manure production

In total, 120 samples of manure treated with the Z'fix agent and 125 samples of untreated manure were analysed over the experimental period. Table 1 shows the results of chemical analyses and averages of ammonia emissions and maximum bedding temperatures. Concerning statistical evaluation, *t*-test at the significance level of 0.5 was used.

When compared to the control variant, the application of the Z'fix agent enhanced quality, structure and nutrient content (N total by 23%, P_2O_5 by 42%, K_2O by 17%) in the manure from deep litter housing. Differences in the nutrient content of N total and K_2O were statistically significant. The optimum development of fermentation and the amount of bedding applied (straw, 5.85 kg/LU/day) led to a significant decrease in NH_3 emissions by almost 35% compared to the control (Fig. 1), to a decrease in maximum temperatures during fermentation from 42–46°C to 25–28°C, and to a reduction in C : N ration from 22.3 : 1 to 18.1 : 1. Fermentation process development manifested a favourable impact concerning bedding stabilisation, cleanliness of animals and their well-being, decrease of labour consumption, extension of bedding hold-up in the cowshed (lower storage capacity requirements), and reduction of costs of manure production.

Jelínek et al. (2004) found a decrease in the NH_3 emissions by 24.0% when employing biological activators, whereas in the study of Brouček et al. (2014), the emission reduction reached 25 to 60%. The application of the Z'fix agent in our study proved good results when utilized in the cowsheds with deep litter housing, and thus it meets requirements of the EU for a decrease in NH_3 emissions in the barns by at least 20%. Dewes (1996) monitored the pH value and temperature during the manure fermentation process.

Economic evaluation of the Z'fix agent employment was based on the certified methodology of Látal et al. (2015). The following parameters were taken into account:

– economic evaluation of costs of the Z'fix agent consumption (20 CZK/kg);

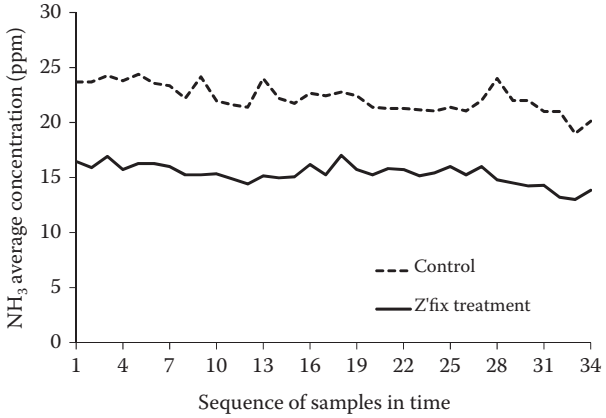

Fig. 1. NH_3 emissions development (averages from 5 locations in each cowshed) with and without the Z'fix agent during the years 2014–2016

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Table 4. Economic evaluation of manure production from deep litter housing of 60 livestock units over the period of 28 months (8/2014–11/2016)

Parameter	Unit	Control (C)		Z'fix treatment		Savings (Z'fix vs control)	
		(No.)	(CZK)	(No.)	(CZK)	(No.)	(CZK)
Z'fix	20 CZK/kg			5,194 kg	103,880		–103,880
Manure production and pricing	Control: 489 CZK/t	1,759.8 t	860,542				
	Z'fix: 556 CZK/t			1 646,4 t	915,398	–113.4 t	54,856
Straw consum.	800 CZK/t	459.9 t	367,920	298,9 t	239,120	161 t	128,800
Dung removal	9,300 CZK	30×	279,000	18×	167,400	12×	111,600
Savings	CZK/28 months CZK/LU/year						191,376 1,369

– economic evaluation of manure pricing (average of years 2014–2016; Tables 2 and 3)
– untreated control manure (489 CZK/t), Z'fix-treated manure with (556 CZK/t)
– economic evaluation of straw savings (800 CZK/t);
– economic evaluation savings due to removal of fresh dung:

1 × JCB loader at 865 CZK/h: 4 h × 865 CZK/h = 3,460 CZK

2 × tractor with trailer at 490 CZK/h:

2 × 4 h × 490 CZK/h = 3,920 CZK

labour costs at 160 CZK/h:

3 workers × 4 h × 160 CZK/h = 1,920 CZK

total costs of 1 × removal of fresh dung from a cowshed = 9,300 CZK.

Economic benefit of manure production using the Z'fix agent compared to the untreated control (Table 4) could be perceived in savings concerning annual costs of straw consumption (lower by 35%), in higher pricing of annual manure production (by 6%), in savings concerning fresh dung removal (at 40%), and in overall savings at the level of 1,369 CZK/LU/year.

Second stage – field trial

Silage maize in 2015 and winter wheat in 2015/16 were used for comparing the effect of application of 50 t/ha (10/2014) of cattle manure treated with the Z'fix agent to the untreated manure (control), including a combination with soil biological transformation activator PRP Sol, on crop yields.

Maize variety SY KAIRO (FAO 250) was sown at the rate of 1 sowing unit on April 27, 2015. Harvest was performed using a standard chopper on September 9, 2015. Control Variant I attained yield of 36.8 t/ha (33% dry matter). Compared to the control, yield of Variant III with the Z'fix treatment was by 4.6% higher. With the application of PRP Sol, the yield of Variant II exceeded the control yield by 5.7%, and the yield of Variant IV surpassed the control yield even by 9.8%. From the economic point of view, an increase in revenues from the chopped forage (calculating 800 CZK/t as a standard price) was by 1,360 CZK/ha higher for Variant III, by 1,680 CZK/ha higher for Variant II, and by 2,880 CZK/ha higher for Variant IV.

Table 5. Harvest yields of silage maize (2015) and of winter wheat (2015/16) with regard to individual experimental variants at ZEPO Bělohrad

Variant	Silage maize		Winter wheat	
	plant yield (33% dry matter) (t/ha)	crude proteins (in dry matter) (g/kg)	seed yield (t/ha)	crude proteins (in dry matter) (%)
I	36.8	89.76	7.63	11.9
II	38.9	83.61	7.68	12.3
III	38.5	84.93	7.85	12.2
IV	40.4	84.72	7.87	12.9
Average	38.7	85.60	7.75	12.3

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Winter wheat variety Turandot was sown at the rate of 200 kg/ha on October 7, 2015, and the harvest took place on August 17, 2016. Control Variant I attained the yield of 7.63 t/ha. Compared to the control, the yield of Variant III with Z'fix treatment was by 2.8% higher. With the application of PRP Sol, the yield of Variant II exceeded the control yield by mere 0.7%, and the yield of Variant IV surpassed the control yield by 3.1%. Plants of Variants II to IV grew taller, and with the use of PRP Sol they also had a sturdier root system. From the economic point of view, an increase in revenues from the wheat seeds (calculating 3,800 CZK/t as a commodity price in 12/2016) was by 836 CZK/ha higher for Variant III, by 190 CZK/ha higher for Variant II, and by 912 CZK/ha higher for Variant IV.

The results concerning increased yields after the application of soil biological transformation activator PRP Sol correspond with the findings of Szücs and Zsembeli (2014) that tested winter wheat and maize yields, and with the results of Sulewska et al. (2016) concerning maize. The beneficial effect was verified as well when growing potatoes (Sulewska et al. 2012), but it was not proved for sugar beet (Podhrázská et al. 2012) and for oilseed rape (Sulewska et al. 2013).

CONCLUSION

Concerning manure production, the application of the Z'fix agent enhanced quality, structure and nutrient content (N total by 23%, P_2O_5 by 42%, K_2O by 17%) in the manure from deep litter housing compared to the control untreated variant. Differences in the nutrient content of N total and K_2O were statistically significant. Compared to the control, NH_3 emissions dropped significantly by almost 35%, and the maximum temperatures during fermentation decreased from 42–46°C to 25–28°C. Fermentation process development manifested a favourable impact concerning bedding stabilisation, cleanliness of animals and their well-being, a decrease of labour consumption, and extension of bedding hold-up in the cowshed (lower storage capacity requirements). Economic benefit of manure production with the use of the Z'fix agent compared to the untreated control demonstrated annual cost of straw consumption lower by 35%, pricing of annual manure production higher by 6%, savings concerning fresh dung removal at 40%, and overall savings at the level of 1,369 CZK/LU/year.

The influence of manure produced combined with the PRP Sol application was tested in terms of boost of crop yield potential of silage maize and of winter wheat. Compared to the control, both crops attained yields higher by 4.6% and 2.8%, respectively, with Z'fix-treated manure. When PRP Sol was applied, yields surpassed the control by 5.7% and by 0.7%, respectively. When both Z'fix and PRP Sol were employed, yields exceeded the control by 9.8%, and by 3.1%, respectively.

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