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EFFECT OF LOCALITIES AND ORGANIC FERTILIZERS ON YIELD IN CONDITIONS OF ORGANIC FARMING

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Abstract

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Nitrogen fertilization cannot be used by actual needs of plants during vegetation in organic farming. The proper crop rotation and harmonic nutrition are necessary for good and quality products. The methods of treatment are mainly realized by cultivation of green manure crop and fertilizing by organic fertilizers. The aim of the long-term experiment was to evaluate the effect of different localities and different organic fertilizers on crop yield in organic farming. Variants of fertilization included in the experiment are: 1. Unfertilized control, 2. Green manure, 3. Green manure + renewable external sources, 4. Green manure + renewable external sources + auxiliary substances, 5. Green manure + farm fertilizers, 6. Green manure + farm fertilizers + auxiliary substances. The experiment started by sowing of winter wheat so green manure crop was not grown in the first experimental year. The highest yield of winter wheat grain coming from the first year of the experiment was observed on the variant with renewable external sources (digestate). Average grain yield on this variant was about 7.12 t/ha (up to 0.74 t/ha increased than the unfertilized control). Average yield of potatoes from the second year of the experiment was the highest after combination with green manure + renewable external sources (compost + digestate) + auxiliary substances. This variant achieved yield about 34.08 t/ha, which is increased by 9.35 t/ha compared to the control variant. Results from this two-year experiment showed that the most suitable combination of fertilization with or without green manure crop is compost + digestate. These results were probably caused by higher content of nitrogen in organic fertilizers (compost + digestate) used in this variant compared to other variants. Statistical difference of achieved yields was observed between each experimental station in both experimental years.

Keywords: organic farming, organic fertilization, yield, winter wheat, potatoes

INTRODUCTION

Organic agriculture is a production system with a particular attention to the environment and its individual components which is currently a well-known concept among lots of people. Environmental protection is possible due to the restriction or prohibition of the use of certain burdensome substances, especially synthetic nitrogen fertilizers. However, content of nutrients from agro-ecosystem even in organic farming is decreasing because of production export and nutrient losses such as leaching or volatilization. The precursor for higher yield and quality of products is good and fertile soil (Dvorský, Urban 2014). Organic farming, in comparison with conventional farming methods, cannot count on the fact that plants can be fertilized directly to the roots according to actual needs in vegetation. The point of emphasis in organic farming is the content of organic matter and quality of humus in the soil.

Currently, the crucial nutrient is still nitrogen. However, balance of nitrogen in organic farming is relatively well solvable. The basis of nutrition in organic farming should be a proper crop rotation (Urban *et al.* 2003). The supply of nitrogen from external environment is primarily achieved by growing legumes and plants suitable for green manure. Another invaluable sources of nutrients are organic fertilizers, especially manure and slurry but also organic compost and increasing use of digestate. The combination of well-chosen crop rotation with adequate dose of properly selected organic fertilizer is very important and proves irreplaceable role for organic farming (Baker, 2010).

A lot of experiments were performed to research and obtain knowledge about organic farming. However, these experiments were mostly established as a short to medium-term researches. The aims of these experiments were also to explore only one area, such as crop rotation, fertilization, soil condition, or pest/weed control. The only long-term experiment was established in FiBL Switzerland in the 1972 (Maeder *et al.* 2002, Fliess 2007). The absence of similar long-term experiment in Czech Republic resulted in creation of unique field experiment in condition of organic farming. This experiment is first systematic attempt to evaluate the influence of organic farming to soil, plant nutrition and yields.

This work is a part of mentioned long-term experiment established in 2014 by the Central Institute for Supervising and Testing in Agriculture. The final aim of this experiment was to evaluate the effect of different localities and different organic fertilizers on yields in terms of organic farming.

MATERIALS AND METHODS

Experimental stations

Small plot field experiment was established as a precise and long-term research. The experiment took place at 5 different experimental stations representing different production areas. Experimental stations are sorted according to more or less suitable soil and climate conditions (Tab. I). The experiment started in spring of 2014. Fields of each location were left as fallow. This period served as the protection against weed. The soil in each experimental station was analyzed before the start of experiment. Results of soil analysis according to Mehlich III and the content of mineral nitrogen are shown in Tab. II. The nitrate nitrogen was determined using ion-selective electrode (ISE), the ammonia nitrogen was determined in Indolphenol spectrophotometry (Zbíral *et al.* 2004). The content of mineral nitrogen (N_{min}) was determined according to summing nitrate and ammonia nitrogen. The soil was collected by a manual soil probe in soil profile in the range of 0–30 cm.

I: *Characteristics of experimental stations*

Experimental station	Characteristics					
	Meters above sea level	Production area	Reference Soil Groups	Soil texture	Average annual precipitation (mm)	Average annual temperature (°C)
Věrovany	207	sugar beet	chernozems	clay	502	8.7
Čáslav	260	sugar beet	chernozems	clay	555	8.9
Jaroměřice nad Rokytnou	425	cereals	luvisols	clay loam	481	8.0
Horažďovice	475	potatoes	cambisols	sandy loam	585	7.8
Lípa	505	potatoes	cambisols	sandy loam	594	7.5

II: *Result of soil analysis before the start of the experiment in each experimental station (October of 2014)*

Experimental station	Content of nutrients (mg/kg)						
	P	K	Ca	Mg	NO_3^-	NH_4^+	N_{min}
Věrovany	106.3	214.8	3184	135.8	35.3	0.4	35.7
Čáslav	65.6	172.2	3082	159.3	9.3	0.2	9.5
Jaroměřice nad Rokytnou	89.5	200.0	3017	210.5	8.6	0.5	9.1
Horažďovice	78.7	143.3	1711	150.6	17.6	6.4	24.0
Lípa	68.6	77.1	2261	111.6	12.8	0.8	13.6

Methodology of experiment

The experiment tried to compare different organic fertilizers simulating systems with or without breeding livestock in organic farming. Each variant had three repetitions. Minimum size of harvested plot was 10 m^2. The yields of winter wheat were evaluated in first experimental year. The yields of potatoes were evaluated in the second year of the experiment.

Winter wheat was sown in the autumn of 2014 as a first model crop in each location. In the first year of the experiment, no sowing or incorporation of green manure crop was applied. Fertilization of winter wheat is described in Tab. III. Auxilary substance (As) for winter wheat was applied two times in May. Auxiliary substances, used in the experiment, for fertilization of winter wheat were based on the extract of seaweed *Ascophyllum nodosum* + mixture of natural, water soluble oligopeptide, amino acids, magnesium, potassium and trace elements. The harvest of wheat was performed at the end of July.

The application of compost and manure (for experimental year of 2016) was performed in August of 2015. Green manure crop (*Pisum sativum var. arvense*) was sown immediately after the incorporation of the organic fertilizers. The average yield of green manure ranged between 0.5 to 4.7 t/ha (depending on experimental station) in dry matter. Green manure was incorporated into the soil by mulching before winter. The fertilization of potatoes is described in Table 4. Planting of potatoes was approximately carried out 14 days after the incorporation of organic fertilizers to the soil in early April of 2016. The Auxiliary substance for potatoes was applied two times in May. Auxiliary substance, used in the experiment, for fertilization of potatoes was based only on mixture of natural, water soluble oligopeptide, amino acids, magnesium, potassium and trace elements. Harvest of the potatoes was performed at the first half of September.

Contents of nitrogen in organic fertilizers are described in Tab. V. Digestate, fermented urine and compost were delivered and used from the same sources for each locality in both experimental years. Each experimental station produced the own manure.

Statistical analysis

The obtained results were evaluated by two factors analysis of variance (ANOVA) with subsequent verification based on Tukey test. The data were processed using the STATISTICA

III: *Variants of winter wheat fertilization*

Variants of fertilization	Organic fertilizers		Auxiliary substances (As)	
	Dose of fertilizer	Date	Dose	Date
1.Unfertilized	-	-	-	-
2. Renewable external sources	14 t/ha of digestate	April 2015	-	-
3. Renewable external sources + As	14 t/ha of digestate	April 2015	5 l/ha	2 applications in May
4. Farm fertilizers	14 t/ha of fermented urine	April 2015	-	-
5. Farm fertilizers + As	14 t/ha of fermented urine	April 2015	5 l/ha	2 applications in May

As – Auxiliary substances: magnesium as MgO – min 4.0 %, potassium as K2O – min 1.0 %, boron as B – 0.04 %, manganese as Mn – 0.1 % , copper as Cu – 0.05 %, molybdenum as Mo – 0.001 % , zinc as Z – 0.2 % , iron as Fe – 0.04 %.

IV: *Variants of potatoes fertilizations*

Variants of fertilization	Application of organic fertilizers				Auxiliary substance (As)
	Dose of fertilizer	Date	Dose of fertilizer	Period	Date and period
1.Unfertilized	-	-	-	-	-
2. Green manure (GM)	-	-	-	-	-
3. GM + renewable external sources	27 t/ha of compost	Autumn 2015	14 t/ha of digestate	April 2016	-
4. GM + renewable external sources + As	27 t/ha of compost	Autumn 2015	14 t/ha of digestate	April 2016	5 l/ha 2 applications in May
5. GM + farm fertilizers	27 t/ha of manure	Autumn 2015	14 t/ha of fermented urine	April 2016	-
6. GM + farm fertilizers + As	27 t/ha of manure	Autumn 2015	14 t/ha of fermented urine	April 2016	5 l/ha 2 applications in May

As – Auxiliary substances: magnesium as MgO – min 4.0 %, potassium as K2O – min 1.0 %, boron as B – 0.04 %, manganese as Mn – 0.1 % , copper as Cu – 0.05 %, molybdenum as Mo – 0.001 % , zinc as Z – 0.2 % , iron as Fe – 0.04 %.

V: *Nitrogen content in organic fertilizers*

Year of application	Organic fertilizer	Nitrogen content (%)
April of 2015 – wheat fertilization	Digestate	0.75%
	Fermented urine	0.05%
Autumn in 2015 – incorporation to soil after wheat harvest	Compost	0.43%
	Manure	0.38% Čáslav
		0,42% Horažďovice
		0.73% Věrovany
		0.86% Jaroměřice nad Rokytnou
		0.90% Lípa
April of 2016 – potatoes fertilization	Digestate	1.37%
	Fermented urine	0.06%

CZ 12 (StatSoft,Inc., USA). Results are expressed as a mean ± standard deviation.

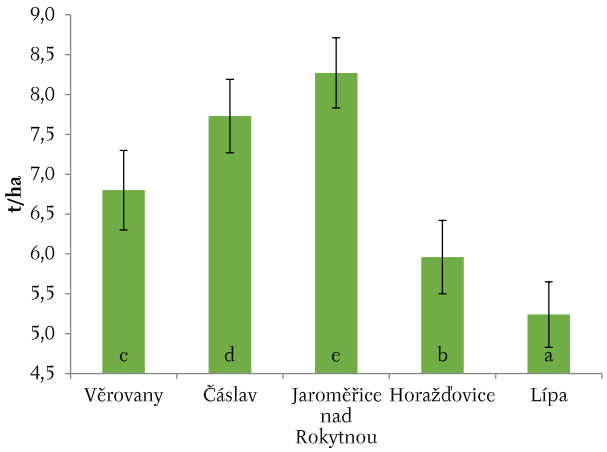
RESULTS AND DISCUSSION

Yields of winter wheat grain in 2015

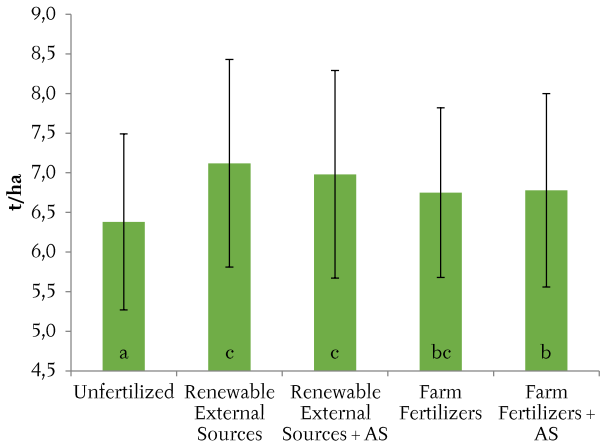
The results show statistically significant difference between each experimental locality as can be evident from Fig. 1. Characteristic of each station is displayed in Tab. I and Tab. II. Each locality had different prerequisites for achieving the optimal yields. Average yield of winter wheat was about 6.36 t/ha in the Czech Republic in 2015 (CZSO, 2016a). Average yield achieved in experimental stations Horažďovice and Lípa was found out lower than in the national average. But these results are obtained from organic farming. The average yield of grain, achieved in the experiment from each station, can be evaluated as suitable. For example, the result obtained from the experiment performed by Rieux *et al.* (2013) shows that the use of animal manure for wheat production appears to be an interesting alternative to mineral fertilization.

Grain yield, achieved at Věrovany, was determined up to 100% due to appropriate soil and climate conditions this station. A decrease by 12% was found out at station called Horažďovice and 24% at Lípa. These experimental locations are characterized by the worst soil conditions in the experiment. On the other hand, yield of grain was increased in Čáslav (12%) and in Jaroměřice nad Rokytnou (22%). These experimental stations are characterized by similar soil and climate conditions as a reference to Věrovany station. Increased yield on these stations is caused by more optimal weather course during the experimental year.

Fig. 2 shows average yields of grain and their statistical significance for each variant of fertilization in the first year of the experiment. Each variant in average provides higher yields compared to unfertilized control. Variants of unfertilized (6.38 t/ha), renewable external sources (7.12 t/ha) and farm fertilizers (6.78 t/ha) were statistically different. A relatively good supply of nutrient was found out in each locality before the start of the experiment (Tab. II), so the average achieved yields were not detected in a such different way. One-fertilization by organic fertilizers was carried out in the first year of this experiment (Tab. III). The best results at most experimental stations were provided by variants 2 and 3 with renewable external sources (+ AS). Variant 3 provided also the best



1: *Average grain yield of winter wheat in experimental stations (2015)*



3: *Average grain yield of winter wheat after different variants of fertilization (2015)*

average yield (11% bigger compared to unfertilized control), as evident from Fig. 2. Variants with farm fertilizers provided lower grain yield compared to renewable external resources probably because of lower nitrogen content in applied organic fertilizers (Tab. V).

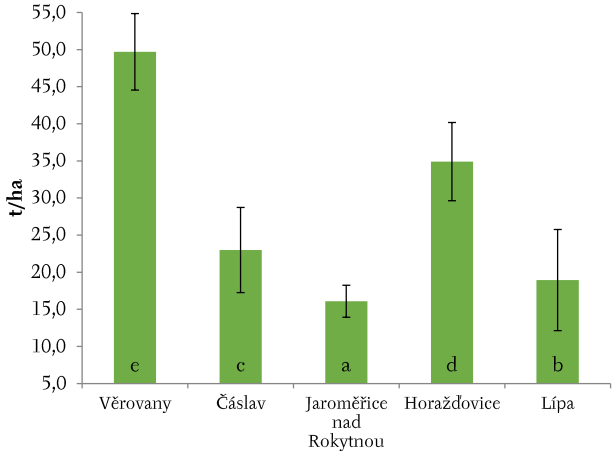
A higher statistical difference between variants is expected in next years of the experiment due to the incorporation of green manure and decreasing content of nutrients in the soil on less fertilized variants.

Yield of potatoes in 2016

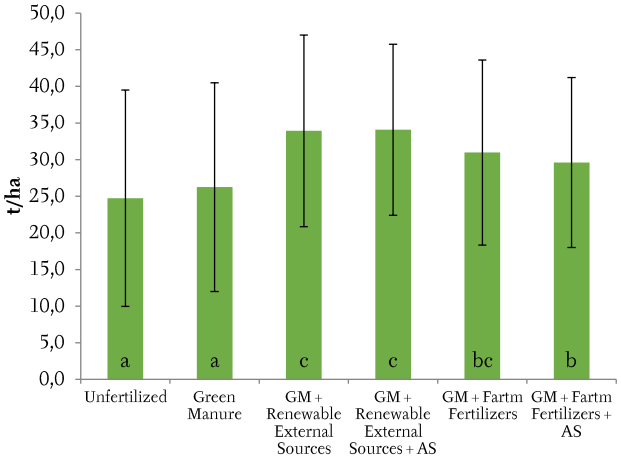
The impact of experimental station was again evaluated as a statistically significant. The average estimated yield of potatoes in the Czech Republic in 2016 was about 29.43 t/ha (CZSO, 2016b). It is seen from Fig. 3 that only two experimental stations (Jaroměřice nad Rokytnou and Lípa) achieved higher yields. However, it is again a good result for organic farming. For example, results obtained from experiment performed by El-Sayed *et al.* (2015) and Plaza *et al.* (2013) proved that organic production of potatoes could be an alternative method to conventional production without significant reduction of yield.

Reference location was determined again the station in Věrovany (100%) due to the best soil and climate conditions. The achieved yield on this locality is very high because of optimal course of weather during the year. Potatoes yields achieved from every other station were detected lower compared to reference station (Fig. 3). This fact was caused mostly by drought in these stations during the experimental year of 2016 (especially in germination and after emergence of potatoes). The lowest yield was noticed in the stations Lípa (62% lower than Věrovany) and Jaroměřice nad Rokytnou (68% lower than Věrovany)

There is also a great statistical difference between examined variants (Fig. 4). Unfertilized control and variant with only green manure provided similar yield. Green manure itself could not fully substitute the incorporation of organic fertilizers. Variants with organic fertilization provided better crop yield. This is a different result compared to the experiment performed by Makarewicz *et al.* (2015). Their results showed, that fertilization with green manure itself



2: *Average yields of potatoes in the experimental stations (2016)*



4: *Average yields of potatoes after different variants of fertilization (2016)*

fully substituted manure in the production system of potato cultivation. The same situation is evident from the variants 3 and 4 with GM + renewable external sources and then from the variants 5 and 6 with GM + farm fertilizers. The variants 3 and 4 with GM + renewable external sources provided again the highest yield. The yield of these variants was increased by about 9.2 t/ha (37%) compared to the control variant. Most importantly, there was also an increase of yield compared to the variants with GM + farm fertilizers by 2.96 t/ha and 4.48 t/ha.

The two applications of organic fertilizers were carried out for potatoes. Compost and manure were incorporated in the autumn of 2015 and digestate and fermented urine were applied in the spring of 2016. Each station used its own manure with a slightly different content of nitrogen, as evident from Tab. V. Compost was delivered to each station from the same sources. A commonly used threshold suggested that amendments with C/N ratios less than 20 can cause quickly net mineralization (Loecke et al. 2012). The ratio of compost in this case was up to 9:1, which was a very thin ratio. This fact lead to a very rapid decomposition (Gale et al. 2006) compared to incorporated manure. According to some authors (Miller et al. 2009, Larney et al. 2006), compost application may appear as more efficient method compared to manure because compost contained more concentrated nutrients due to significantly less level of C, less water amount and reduced potential for N loss through volatilization in time of application.

Digestate and fermented urine were also delivered to each station from the same sources. Average nitrogen content in fermented urine is around 0.23% but content of N in fermented urine used in this experimental year reached up to 0.06%. The nitrogen content was highly variable and dependent on the strong dilution with water. 90% of nitrogen in fermented urine was in easily soluble form with the largest share of ammonia nitrogen (Urban *et al.* 2003). The application of fermented urine was also problematic due to volatilization loss of ammonia (Mahimairaja *et al.* 1994). Digestate applied in the experimental year of 2016 contained even more nitrogen than fermented urine compared to year of 2015. Digestate also had a large proportion of highly usable ammonia nitrogen (Moller and Muller 2012). Therefore, the variants with GM + renewable external resources provided higher potatoes yield compared to the combination with GM + farm fertilizers because of higher nitrogen content in applied organic fertilizers (Tab. V). The result obtained from the experiment performed by Smatanová (2012) also showed a great increase of potato yield after the fertilization with digestate or compost compared to the control variant.

CONCLUSION

The results obtained from the first two years of the experiment showed that any application of organic fertilizers either from green manure itself, renewable external resources or farm fertilizers proved the increasing yield compared to unfertilized variant. This result was not obviously surprising. However, in organic farming, it is not possible to rely on crop fertilizing during vegetation according to the current needs. The application of any organic fertilizers played therefore a crucial role for plants and yields. Green manure in practice is often cultivated as a winter or stubble crop with a short growing period. Incorporation of such green manure itself did not provide enough organic matter and decomposed rapidly. The results from the second year of this experiment confirmed that the variant with green manure itself provided better yields compared to unfertilized variant but the difference was not detected statistically significant.

A statistical difference between the examined variants of fertilization was found out in both experimental years. The obtained results showed, that the highest yields of wheat grain and potatoes were provided by the combination of compost and digestate. Organic fertilizers used in this variant contained more nitrogen in comparison to other variants of fertilization. The idea came out that compost provided more nutrients for plants in the first year after the incorporation compared to manure which was supported by the result of this experiment.

A lot of auxiliary substances are allowed to be used in organic farming. As mentioned before, one of the examined enriched variants provided high yield. But if we compare these enriched variants to the same variants without AS, the results obtained from this experiment then showed that the application of auxiliary substances in organic farming did not provide any statistically different yield compared to the same variant of fertilization without AS.

Statistical difference of achieved yields was observed between each experimental station in both experimental years. This result was only a confirmation that the production of yields was heavily dependent on the content of nutrients in soil, good soil condition and optimal course of weather (mostly precipitation) during vegetation.

The result from this experiment indicated that farming without livestock may be as effective as the production with livestock. However, this result was caused probably by the higher content of nitrogen in compost and digestate compared to farm fertilizer. The obtained results were also found out from two experimental years so further research should follow to show detailed facts.

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