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ECONOMIC EFFICIENCY OF FERTILIZATION AND ITS RESIDUAL-EFFECT DURING CONVERSION PERIOD TO ORGANIC FIELD CROP PRODUCTION

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Abstract

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The transformation of a conventional production system to an organic one passes through the obligatory period of conversion, when the farmers are obliged to apply all restrictions for organic production. Most of the farmers bear losses because of the lower productivity of crops during the period of conversion and the additional expenses necessary to be made (certification of production). At the same time their products are realized at the price of conventional crops. The study was based on à long term field fertilizer experiment conducted by the Department of Agrochemistry and Soil Science at the Agricultural University – Plovdiv. Since 2006, fertilization of crops in the rotation was excluded. The aims of the study were to determine the economic effectiveness of fertilization in conditions of conventional production and the residual-effect of fertilization during the period of conversion to organic production. The following indicators were used: additional yield (kg.ha^{-1}), cost of fertilization (BGN.ha^{-1}), additional income from fertilization (BGN.ha^{-1}), additional profit from fertilization (BGN.ha^{-1}), cost-effectiveness of fertilization (%), and residual effect of fertilization - additional profit (BGN.ha^{-1}). The results of the study proved that systematic fertilization before the period of conversion, selection of a suitable rotation and elimination of the expenses for fertilization generate incomes comparable to incomes accumulated from conventional production - from 1507.75 to 4596.97 BGN.ha^{-1}.

Key words: conversion to organic production, expenses, profit, crop rotation

Introduction

In recent years, worldwide and in Bulgaria demand for cleaner and healthier food has been growing. As a result an increasing number of farms convert from conventional production to organic one. When a farmer decides to change his/her production system from conventional to organic, the question he faces is how to overcome the period of conversion with a minimum reduction of yields and profits. Every conventional farm must undergo a 2 years period of conversion in order to be certified as an organic farm. During that period farmers are obliged to apply the limitations of the organic production and to pay for certification of the production but they can not benefit from the higher prices of analogous organic products. Usually during this period producers suffer losses due to yields reduction. Efficiency is very important for every type of production system in agriculture. The main advantage of the modern intensive management systems in agriculture is higher profitability. But in the long term they lead to problems, connected with sustainability and environment.

Many studies proved reduction of field crop yields from organic fields in comparison to conventional ones. The rate of decreasing yield varies a lot in different studies, sites and countries. Research conducted in Maryland USA showed 6% lower yields from organic wheat (2.95 t.ha^{-1}) in comparison to conventional yields (3.14 t.ha^{-1}) (Teasdale et al., 2007). Researchers from Switzerland (Mader et al., 2002) found out 11% decrease in wheat yields - from 4.6 to 4.1 t.ha^{-1}. Other

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authors (Stalenga, 2007; Kirchmann et al., 2007; Pelosil et al., 2009) reported the most severe decreasing of wheat yield on organic wheat (from 31 to 41%) in Poland, Sweden and France. Lower yields (66%) in organic spring wheat (from 3.28 to 1.12 t.ha^{-1}) were announced in Canada (Welsh et al., 2009). Considerable yield reduction was found with barley from 44 to 49% (Kirchmann et al., 2007; Torstensson et al., 2006). A trial carried out in Germany reported 16% reduction in maize yield (from 11.79 to 9.94 t.ha^{-1}) (Burger et al., 2008). Several researches have shown that more diverse crop rotations, often due to higher yields and somewhat lower input costs result in higher net returns (Welsh, 1999; Chavas et al., 2009; Delate et al., 2009). Comparing net returns of conventional and organic field crop rotation almost the equal values for both cropping systems were reported even when organic price premium was excluded (Delbridge et al., 2011).

Yields depend most heavily on plant nutrition, so we focus on fertilization and its residual-effect. Our assumption was that by adopting appropriate design of crop rotation and preliminary building up of available forms of nutritional elements in the soil by fertilization, producers could be able to rely on the residual-effect of fertilization applied in the preceding rotation. This could allow them to soften yields and income reduction from crops during the critical period of conversion. The purpose of this study was to determine the economic effectiveness of fertilization and residual-effects of different fertilizing systems in conditions of field crop rotation. From scientific point of view this evaluation poses considerable interest. Furthermore, farmers willing to convert their production to an organic one would find the study especially helpful.

Materials and Methods

The study was based on the results of a long term field fertilizer trial conducted in the experimental field of Department of Agrochemistry and Soil Science at Agricultural University, Plovdiv (Rachovski et al., 2010). The experiment began in 1959. Eight field crop rotations have been realised since that time. The experiment was carried out on Mollic-Fluvisols (FAO). The method with adjacent standards with four replications was applied. The size of the experimental plots was 75 m^2. The last crop rotation with included fertilization was: maize - wheat - field pea – barley (2003-2006). The same rotation was applied during the 3 years period (2007-2010) of the experiment but without fertilization of the crops. The fertilization rates (variants of the experiment) per ha for whole rotations were: control (unfertilized), $N_{250}P_{300}K_{200}$, $N_{500}P_{300}K_{200}$, $N_{750}P_{300}K_{200}$, $N_{250}P_{300}K_0$ + 60 t/ha manure and $N_{500}P_0K_{200}$, $N_{500}P_{300}K_0$. The following methodical approach was applied for assessment of the economic effectiveness of fertilization: on the first stage a cost-effectiveness of fertilization of the last crop rotation was determined. On the second stage the residual effect of fertilization on crop productivity and financial income was determined for the next rotation, in which fertilization was excluded.

The next indicators used for estimation of efficiency of fertilization were: additional yield (kg.ha^{-1}), cost of fertilization (BGN.ha^{-1}), additional income from fertilization (BGN.ha^{-1}), additional profit from fertilization (BGN.ha^{-1}) and cost-effectiveness of fertilization (%). The additional yield was calculated as a difference between average yields obtained by fertilized plots and control (variant without fertilization). The costs of fertilization included: the cost of fertilizers, their application rates for the last rotation, the cost for transportation and spreading of fertilizers. Additional incomes from fertilization were calculated as the additional yields obtained as a result of fertilization were multiplied by the price of products. The additional profit from fertilization was calculated as a difference between additional incomes and additional costs for fertilizing. The cost-effectiveness of fertilization - is determined as a ratio between the additional profit earned as a result of fertilization and the expenses on fertilization. Materials, products and services are valued at market prices of 2010. Specifically: the cost of fertilizers were calculated at prices - 700 BGN.t^{-1} for ammonium nitrate, 1000 BGN.t^{-1} for triple superphosphate, 1300 BGN.t^{-1} for potassium chloride and 8 BGN.t^{-1} for manure; transport of fertilizers at 1.5 BGN.km^{-1}; fertilizers broadcasting at 11 BGN.ha^{-1}. Transport and broadcasting of manure are estimated at 40 BGN.ha^{-1} and 80 BGN.ha^{-1}, respectively. The value of the production is calculated according to the following prices - 239 BGN.t^{-1} for maize, 252 BGN.t^{-1} for wheat and 1200 BGN.t^{-1} for field pea and barley - 198 BGN.t^{-1}. For comparison: (1 € = 1.9558 BGN).

Measuring the efficiency of the residual effect of fertilization was also attempted using the following indicators: additional yield (kg.ha^{-1}) from residual effect of fertilization, additional profit from residual effect of fertilization (BGN.ha^{-1}) and profit from residual effect of fertilization in comparison with the profit from fertilization (%). These indicators have been calculated in the same way as before.

Results and Discussions

No significant differences were observed in the productivity of the crops grown, which rely on residual effect of fertilizers in comparison with the productivity of the crops from the last rotation with application of fertilizers (eighth rotation from beginning of the experiment) (Table 1). The most severe yield decreasing after the exclusion of the fertilization was determined for maize - from 29.44% (variant 7 - $N_{500}P_{300}K_0$)

to 34.45% (variant 6 - $N_{500}P_0K_{200}$). The results showed slight yield reduction for wheat, barley and field pea.

Higher amounts of additional yields were obtained from treatment with high (750 kg.ha^{-1}) and moderate (500 kg.ha^{-1}) nitrogen fertilizing rates, as well as after application of manure (Table 2). The exclusion of phosphorus (treatment 6) demonstrated a severe decreasing of yields which is better manifested at winter cereals (wheat and barley). The exclusion of potassium from the fertilizing combination (treatments 5 and 7) did not affect yield considerably because of relatively high soil reserves of available forms of the elements in the soil. The same explanation could be made with respect to the obtained additional yields after the exclusion of fertilization (Table 3). Yields obtained confirm the presence of the residual effect of fertilization.

The expenses for fertilization of the last crop rotation (2003 – 2006) are presented in Table 4. The total expenses are higher at variants with greater rates of synthetic fertilizers ($N_{500}P_{300}K_{200}$ and $N_{750}P_{300}K_{200}$) - 2313 and 2843 BGN.ha^{-1} respectively. The total expenses for fertilization of or-

Table 1
Productivity of crops

Fertilizing systems	Maize		Wheate		Forage pea		Barley	
	Last fertilization	Without fertilization	Last fertilization	Without fertilization	Last fertilization	Without fertilization	Last fertilization	Without fertilization
1. Control	7650a	4400a	1560a	1820a	8410a	9100a	1660a	1840a
2. $N_{250}P_{300}K_{200}{}^{*}$	9300b	6180b	3520b	3270b	10540bc	10040b	3160c	3000b
3. $N_{500}P_{300}K_{200}$	9830bc	6830b	4540cd	3810c	12100de	11010c	3900d	3970c
4. $N_{750}P_{300}K_{200}$	10340c	7270b	4340c	4250c	12520e	11410c	4210de	4500d
5. $N_{250}P_{300}K_{400}$ + 60 t/ha manure	10310c	7090b	4910d	4330c	12640e	11100c	4510e	4050cd
6. $N_{500}P_0K_{200}$	9260b	6070b	1640a	2070a	10000b	9940b	2600b	2030a
7. $N_{500}P_{300}K_0$	10020c	7070b	4160c	3850c	11280cd	10180b	4240de	4200cd

Table 2
Additional yield compared to control, result from different fertilizing systems, kg/ha

Fertilizing systems	Maize	Wheat	Forage pea	Barley
1. Control	0	0	0	0
2. $N_{250}P_{300}K_{200}{}^{*}$	1650	1960	2130	1500
3. $N_{500}P_{300}K_{200}$	2180	2980	3690	2240
4. $N_{750}P_{300}K_{200}$	2690	2780	4110	2550
5. $N_{250}P_{300}K_{400}$ + 60 t/ha manure	2660	3350	4230	2850
6. $N_{500}P_0K_{200}$	1610	80	1590	940
7. $N_{500}P_{300}K_0$	2370	2600	2870	2580

Table 3
Additional yield compared to control: result from residual effect of fertilizing, kg/ha

Fertilizing systems	Maize	Wheat	Forage pea	Barley
1. Control	0	0	0	0
2. $N_{250}P_{300}K_{200}{}^{*}$	1780	1450	940	1160
3. $N_{500}P_{300}K_{200}$	2430	1990	1910	2130
4. $N_{750}P_{300}K_{200}$	2870	2430	2310	2660
5. $N_{250}P_{300}K_{400}$ + 60 t/ha manure	2690	2510	2000	2210
6. $N_{500}P_0K_{200}$	1670	250	840	190
7. $N_{500}P_{300}K_0$	2670	2030	1080	2360

ganic-mineral system were higher, too ($N_{250}P_{300}K_0$ + 60 t/ha manure) – 2653 BGN.ha^{-1}, because of the large quantities of applied manure. The total expenses for fertilization of organic-mineral system were higher as well ($N_{250}P_{300}K_0$ + 60 t/ha manure) – 2653 BGN.ha^{-1} for the same reason.

Results for economic effectiveness of the fertilization of the last crop rotation (Table 5) showed that all tested variants of fertilization are cost-effective. The obtained profits were from 1069.27 BGN.ha^{-1} (variant 6 - $N_{500}P_0K_{200}$) to 6081.64 BGN.ha^{-1} ($N_{250}P_{300}K_0$ + 60 t/ha manure) higher than control. The highest profit was achieved when organic-mineral fertilization system was applied (6081.64 BGN.ha^{-1}). The economic assessment of fertilization for the sixth crop rotation of the long term trial also showed the organic-mineral fertilization system as the most effective (Manolova and Manolov, 2000; Tomov et al., 2001).

The high profits of fertilization were realized from variant 4 – $N_{750}P_{300}K_{200}$ (5566.17 BGN.ha^{-1}) and from variant 3 - $N_{500}P_{300}K_{200}$ (5190.50 BGN.ha^{-1}). The lowest profit of fertilization was achieved when phosphorus was excluded from the fertilizing combination for a long period of 15 years (1069.27 BGN.ha^{-1}). The continued shortage of the element in the soil led to considerable yield reduction in comparison with other fertilized variants especially at winter cereals - wheat and barley (Table 3). The cost-effectiveness of fertilization was high and varied on a large scale from 62% to 259% (Table 5). Most profitable was the variant $N_{500}P_{300}K_0$ - 259%, which showed the best combination of profit and expenses due to the exclusion of potassium fertilizers. This is the most expensive fertilizer from the NPK combination. Organic-mineral fertilization system $N_{250}P_{300}K_0$ + 60 t/ha manure went to second place (229%), followed by the variant $N_{500}P_{300}K_{200}$ (224%). Cost-effectiveness index had the lowest value for the variant $N_{500}P_0K_{200}$.

In the second phase of the study the residual-effect of fertilization was determined (Table 5). This effect was measured by the additional profit obtained from higher yields of residual-effect of fertilized variants compared to the control (without

Table 4
Expenses for fertilization of the last crop rotation

Fertilizing systems	Number of fertilizer applications for the entire rotation	Expenses for the transport of fertilizers	Expenses for speading of fertilizers	Expenses for fertilizers	Total expenses for fertilization
1. Control	0	0	0	0	0
2. $N_{250}P_{300}K_{200}^*$	8	45	88	1650	1783
3. $N_{500}P_{300}K_{200}$	8	45	88	2180	2313
4. $N_{750}P_{300}K_{200}$	8	45	88	2710	2843
5. $N_{250}P_{300}K_0$ + 60 t/ha manure	9	165	168	2320	2653
6. $N_{500}P_0K_{200}$	8	45	88	1580	1713
7. $N_{500}P_{300}K_0$	8	45	88	1660	1793

Table 5
Economic efficiency of fertilization of the last crop rotation

Fertilizing systems	Economic efficiency of the last rotation with fertilization			Residual effect of fertilization-aditional profit, BGN/ha	Obtained profit from residual effect in comparison with profit from fertilization, %
	Additional income from fertilization, BGN/ha	Additional profit from fertilization, BGN/ha	Cost effectiveness of fertilization, %		
1. Control	0	0	0	0	0
2. $N_{250}P_{300}K_{200}^*$	4851.67	3068.67	172	2148.5	70
3. $N_{500}P_{300}K_{200}$	7503.50	5190.50	224	3795.99	73
4. $N_{750}P_{300}K_{200}$	8409.17	5566.17	196	4596.97	83
5. $N_{250}P_{300}K_{400}$ + 60 t/ha manure	8734.64	6081.64	229	4113.01	68
6. $N_{500}P_0K_{200}$	2782.27	1069.27	62	1507.75	141
7. $N_{500}P_{300}K_0$	6435.67	4642.67	259	2912.97	63

fertilization). The data shows that the indicator retains high levels of profit in all studied variants. The highest additional profits were obtained from variants with higher nitrogen fertilizing rates (500 and 750 kg.ha^{-1}) combined with moderate phosphorus and potassium rates ($P_{300}K_{200}$), as well as a variant with organic-mineral fertilization. The highest additional profit at these variants varied from 3795 to 4596 BGN.ha^{-1}. This data could be explained with the residual-effect of long term fertilization on the productivity of crops and positive effect of suitable crop rotation (inclusion of leguminous crop).

The elimination of costs for fertilization also led to increasing of additional profit. The obtained profit from residual effect of fertilization during conversion period was from 17 to 37% smaller in comparison with the profit obtained during the period when fertilizers were applied. This reduction of profit could be explained mainly with the decrease in maize yields after the exclusion of synthetic fertilizers while the yields from wheat, barley and field peas were comparable with yields obtained during years with synthetic fertilizer application. The results of the conducted experiment confirm the hypothesis that the application of appropriate crop rotation and reserved fertilization lead to long lasting residual-effects of fertilization and high economic effect for farmers.

Conclusion

The obtained results prove that the greatest economic efficiency in field crop rotation is realized after the application of organic-mineral fertilizing systems ($N_{250}P_{300}K_0$ + 60 t/ha manure). Mineral fertilizing systems - $N_{500}P_{300}K_{200}$, $N_{500}P_{300}\hat{E}_0$ and $N_{750}P_{300}K_{200}$ can also be classified as highly economic effective. The systematic application of N, P and K mineral fertilizers during the years preceding the period of conversion build up soil reserves of available nutrients forms which soften the effect of prohibition of application of such types of fertilizers in organic farming during conversion period when natural ecological balances in the soil are restored.

Optimal fertilization in the period before the conversion from conventional to organic production, selection of a suitable rotation (inclusion of leguminous crops) and the elimination of the costs for fertilization can increase producers' profits per unit area from 1507.75 to 4596.97 BGN.ha^{-1}, comparable to those in conventional production. The profit achieved during the conversion period depends on the type of fertilization plan applied on the field when only conventional crops were grown.

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