# STABILITY OF THE YIELD POTENTIAL IN ECOLOGICAL AGRICULTURE*

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During the fifteen-year long observation of ecological experiments conducted according to the rules of IFOAM (International Federation of Organic Agriculture Movement) and the regulations of the Ministry of Agriculture Czech Republic, the yields of winter wheat were evaluated as an indicator of the production potential of an ecological growing system. The average yield of 28 varieties during the period of 1994 to 2008 was 6.42 t/ha, the standard deviation of ± 1.13 t, with the variation coefficient of 17%. The yield of wheat in ecological agriculture is formed by the productivity of the ear, i.e. the number of grains and its mass. It is also associated with the dynamics of the nitrogen release, which is highest during the period of the generative organs formation. Varieties with high ear productivity were shown to be suitable for ecological agriculture. One of the criteria of the system sustainability is a permanently good level of available nutrients in the soil. The variation coefficient of the contents for individual nutrients is 10.2–19.5%. There was no reduction in the contents of available nutrients during the entire period, which indicates that the ecological system of farming was not depleting the soil. The sources of nutrients come form intensive weathering, atmospheric fallout, mineralisation of organic matter in the soil following the pre-crops, and symbiotic fixation of nitrogen by legumes and pulse crops.

ecological agriculture; wheat yield; yield elements; production potential; sustainable agricultural system

## INTRODUCTION

Ecological agriculture has already become an inseparable part of the entire agrarian sector. In 2008 its share in the Czech Republic has reached nearly 8 percent of agricultural land, and it is expected its future growth will reach up to 20% of agricultural land. The demand for bioproducts is rising even more in the neighbouring countries to which a significant proportion of the local production is destined. However, the main stimulation for the advancement of ecological agriculture is an incentive bonus for ecological farmers. Apart from the bioproduction as such, the considerate treatment of the environment and the landscape is also appreciated here.

Ecological agriculture must now be considered to be an independent system of farming on the soil. It is a specific agricultural ecosystem which, just like in conventional farming, requires a certain competitive ability given, first of all, by the quality of the bioproducts but, in the main, by the careful treatment of the environment, agricultural-forest landscape, and considerate treatment of farm animals.

One of the goals of ecological agriculture is the maintenance of soil fertility. There is a lot of evidence this agricultural system has a character of sustainable agriculture. For instance, L e h o c k á et al. (2008) reports the results of a positive influence of ecological agriculture on the soil pH and on the increase in organic matter in the soil, as well as on the microbiological activity in the soil. Š a r a p a t k a et al. (2008) also demonstrated a higher proportion of organic matter and thus a higher occurrence of epigeon fauna and greater biochemical soil activity. The research of these and other authors also confirmed the influence of ecological agriculture on the biological activitity in the soil and the occurrence of different groups of edaphon and epigeon.

Experiments conducted by F l i e s s b a c h et al. (2006) over a period of 21 years on ecological as well as conventional plots, similarly confirmed the favourable effects of ecological farming on the biological activity of the soil and its production potential.

This study presents the results of ecological farming over a period of 15 years on the production potential of the soil and contents of available nutrients, including mineral nitrogen in the soil. We intend to verify the hypothesis that ecological agriculture is a sustainable system of farming.

## MATERIAL AND METHODS

Since 1991 the Czech University of Life Sciences Prague has carried out research and education in ecological agriculture. The research is supported by the university's Experimental Station in Prague-Uhříněves, which conducts experiments in accordance with international methodology of IFOAM and the regulations of the Ministry of Agriculture of the Czech Republic (Act 242/2000 and the EHS Board 2092/91).

Following an interim period, we have been establishing varietal and agricultural technology experiments with selected crops since 1993. The Station is certified for ecological agriculture and is inspected every year. The plots

* The research was supported by Grant Project of the Ministry of Agriculture of the Czech Republic NAZV QG 50034 "Nové technologické postupy v ekologickém zemědělství na orné půdě k získání kvality pro potravinářské a krmivářské využití" and Project No. 6046070901, Ministry of Education of the Czech Republic.

are located in a fertile sugar beet region with an average altitude of 295 m and a production potential of the soil being 84 points, which is a very high value. The soils are brown soils on the soilforming loess substrates. They are clay soils with the topsoil depth down to 32 cm and with a humus horizon down to 70 cm. The topsoil contains medium to moderate amount of humus with the content of 1.74 to 2.12%.

The water table is at the depth of 1 m and is of a permanent character. A favourable water regime is based on developed illuvial horizons with a relatively good water retention, which has an effect on the stable content of available moisture. The average annual temperature of the air in this area is 8.45°C, and the average total precipitation reaches 575 mm, of which 380 mm falls during the period from April to September. On average, in the long term, most precipitation falls in June and July, least in February. The region is semi-humid.

The varietal experiment with 28 varieties was established using the methodologies of National Plant Variety Office by the method of randomised block with three replicates, with the blocks of 10 $m^2$ each. The experiment pre-crops were either red clover (*Trifolium pratense*) or a pulse crop-cereal mixture for green manure.

The reserves of available nutrients in individual years have been continuously evaluated according to Mehlich as good. The mineral nitrogen content has been determined by an extract in 1% KCl and by the photometric method using the Skalar equipment. After a three-year intermediate period and fifteen years of farming we have an opportunity to judge the effect of long-term ecological farming on the maintenance of the production potential of soils and the nutrients reserves in the soil. We are documenting the production potential by the winter wheat yields and the contents of available nutrients in the soil.

## RESULTS AND DISCUSSION

The largest range of experiments in the ecological system is taken up by varietal experiments carried out in individual years with the same varieties and using the same methodology as those in the state varietal experiments by the National Office for Varieties of the Czech Republic. They are conducted under conventional conditions using different intensity of cultivation. In our experiments we test the suitability of the varieties for the conditions of ecological farming.

The results of the varietal experiments with winter wheat are presented in Fig. 1, which shows the yields ranging from 4.37 do 8.55 t/ha. The average yield of the 28 varieties observed annually for the entire experimental period was 6.42 t/ha, with the standard deviation of 1.13 t and the variation coefficient of 17%. It is certainly possible to consider these results as a proof of the ecological farming system's sustainability.

The results of observations over 9 years (Table 1) make it possible to evaluate the structure of the yields on the basis of the average of 28 tested varieties. From the average sowing rate of 400 caryopsis per 1 m², 270 plants germinated, of which 77% survived winter so that, on average, 208 plants per 1 m² remained in the spring. The result of this structure of the stand is 407 ears per 1 m². It is worthy of note that there was a relatively high number of grains per ear (35.2) and their mass (1.64 g), i.e. the mass of 1000 grains was 46.6 g.

These results suggest that the yields are based on a high productivity of the ear. For ecological farming it is, therefore, necessary to select varieties with this yield formation character. An explanation is provided by the dynamics of the available nitrogen release from the soil, which is, depending on the type of pre-crops and ploughed in postharvest debris, as well as green manure, moved into the later period when it supports the formation of generative organs (see Fig. 2).

Fig. 2 shows that intensive release of nitrogen started on 15.5. and culminated by the end of June and beginning of July, which happens to be the period of the establishment of the number of the grains and their filling, as well as of the support of the photosynthetic activity of the upper part of the plant and the ear. Thin stands also (through more light, water, nutrients, etc) create via autoregulation

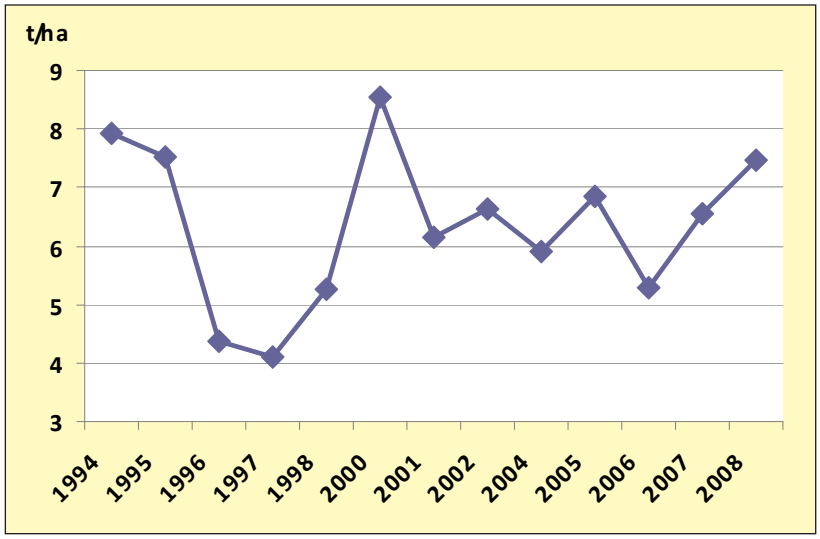


Fig. 1. Yields of winter wheat varieties in ecological agriculture from 1994 to 2008

Table. 1.The structure of the current winter wheat varieties yields in ecological agriculture

| Year | Number of germinated plants per $m^2$ | Over-wintering in % | Number of ears per $m^2$ | Number of grains per ear | Mass of grains per ear in g | Mass of 1000 grains in g | Yield t/ha |
|---|---|---|---|---|---|---|---|
| 2000 | 359 | 90 | 487 | 38 | 1.75 | 45.5 | 8.55 |
| 2001 | 299 | 71 | 414 | 29 | 1.48 | 50.7 | 6.16 |
| 2002 | 304 | 79 | 500 | 30 | 1.30 | 44.1 | 6.64 |
| 2003 | Experiments destroyed by adverse winter conditions | | | | | | |
| 2004 | 201 | 55 | 323 | 34 | 1.82 | 53.5 | 5.91 |
| 2005 | 289 | 90 | 375 | 38 | 1.82 | 47.8 | 6.85 |
| 2006 | 186 | 50 | 335 | 35 | 1.58 | 45.1 | 5.30 |
| 2007 | 267 | 85 | 368 | 40 | 1.78 | 43.9 | 6.55 |
| 2008 | 261 | 96 | 459 | 38 | 1.6 | 42.3 | 7.46 |
| Average | 270 | 77 | 407 | 35.2 | 1.64 | 46.6 | 6.67 |

of the yield elements the conditions for the establishment of a greater number of the bases for the spikelets, florets and future grains. This is associated with the compensation of the yield elements, when with a small number of plants, tillers and ears a higher number of grains is formed and their mass is also greater.

In our experiments the sowing rate of 400 grains per 1 m² and the sowing period in the second half of September proved to be best, as also confirmed by other research workers (B i c a n o v á et al., 2008; P e t r et al., 2008). Increasing the sowing rate above this limit resulted in higher yields only in the cases of late sowing period. At higher sowing rates there is a strong reduction in the number of plants. An ecological agricultural system can support only a certain number of plants per square unit, and it can also support only a certain number of tillers which will bear ears. This is given by the contents and release of available nutrients to the plants.

In the experiments described above there was a stable and good supply of nutrients. The variation coefficient for the phosphorus content was 14.1%, while for potassium it was 19.5% and for magnesium 10.2%. During the entire duration of the experiments the P content remained (except for 1994) in the category of good supply (average of 98.8 mg/kg), the same applied to potassium (average 199 mg/kg of soil), while for magnesium the content was satisfactory (131.5 mg/kg of soil) within a permanent range of 120–150 mg/kg of soil. The ratio of K/Mg was also good – 1.5.

During the fifteen year experiment there has been no decrease in the contents of available nutrients (Fig. 3). It is therefore now possible to confirm with these results the veracity of the hypothesis and also that ecological agriculture does not "plunder" the soil. However, this requires that the cultivating system respects all prescribed principles. In experiments we use the value of legumes as precrops and the importance of green manure in improving the soil. This also determines the quantity of available nitrogen and the dynamics of its release.

During the fifteen year experiment there has been no decrease in the contents of available nutrients. We can mention weathering as a source of nutrients. Š a r a p a t k a , U r b a n et al. (2006) state that under the conditions in the Czech Republic the weathering process releases on one hectare 3 kg P, 12 kg K, 48 kg Ca and 13 kg Mg. Under the conditions of our experiments these figures were even higher, as the soil had a permanently neutral pH 6.8 and it is aired by regular ploughing and several mechanical treatments, which reinforces this process.

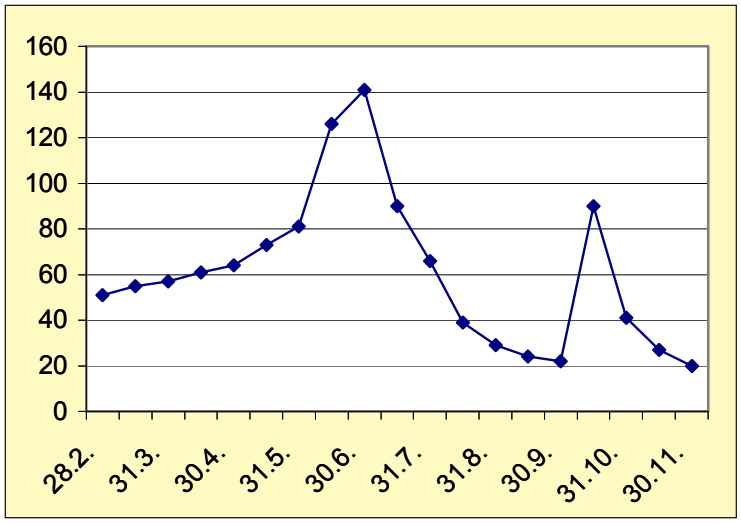


Fig. 2. The content of mineral nitrogen in the soil in kg/ha to the depth of 60 cm

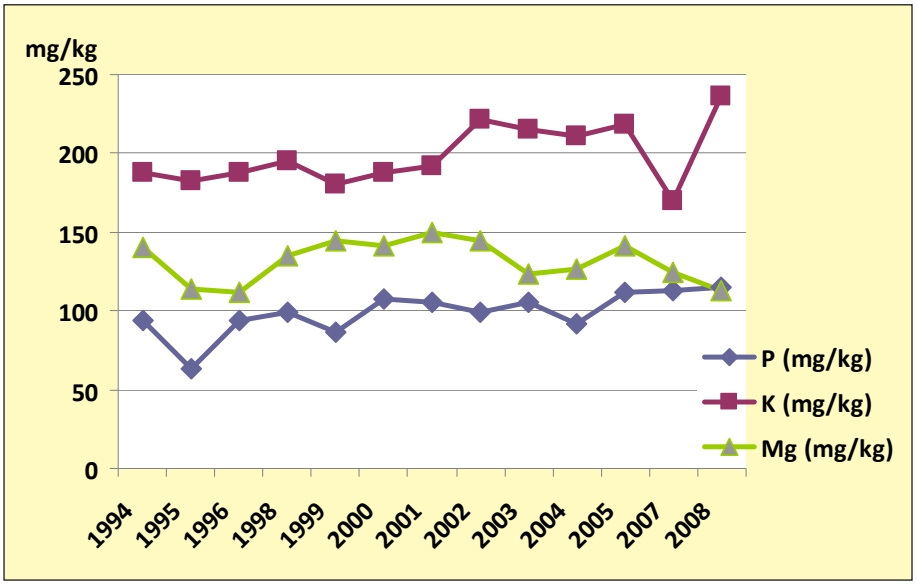


Fig. 3. Contents of available nutrients in the soil between 1994 and 2008

The high flow of organic matter into the soil determines high formation of carbon dioxide and organic acids, which significantly support the release of nutrients. Large quantities of nutrients were released by the decomposition of the postharvest debris of the pre-crops and green manure (red clover and mixture of pulse crops). There is a high level of nitrogen fixation in these crops, which represents up to 150 kg N after clover and up to 70 kg N after pulse crops. Apart from this, the pre-crops also release 10–20 kg of P, 15–40 kg of K, and 60–100 kg of Ca (Čvančara, 1962). Towards the total balance we must also add the atmospheric fallout which provides 20 kg mineral nitrogen, 5 kg of P, 8 kg of K and 15 kg of Mg.

The ploughed in organic mater favourably affects the soil structure and the water regime of the soil. Fliessbach et al. (2006) from the Experimental Institute of Ecological Agriculture in Switzerland demonstrated by the above experiments that in ecological agriculture there is less washing out of nutrients and a smaller susceptibility to water erosion. Šarapatka et al. (2008) confirmed in our experiments the significance of the flow of organic matter into the soil for the development of the epigeon fauna and the biochemical activity of the soil. Thus he confirmed the significance of the long term ecological experiments for a comprehensive view of the agroecological system of ecological agriculture.

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Received for publication on on January 19, 2009
Accepted for publication on February 2, 2009

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**Stabilita výnosového potenciálu v ekologickém zemědělství.**

Scientia Agric. Bohem., *40*, 2009: 53–57.

V patnáctiletém sledování ekologických pokusů vedených podle předpisů IFOAM (International Federation of Organic Agriculture Movement) a předpisů MZe ČR se hodnotily výnosy ozimé pšenice jako jeden z ukazatelů produkčního potenciálu půdy. Průměrný výnos 28 odrůd za období 1994–2008 byl 6,42 t/ha, směrodatná odchylka 1,13 t, variační koeficient 17 %. Výnos byl tvořen 270 rostlinami na $m^2$, počet klasů byl průměrně 407 na $m^2$, v každém klasu bylo 35,2 zrn a hmotnost 1000 zrn byla 46,6 g.

Výnos pšenice v ekologickém zemědělství je tvořen produktivitou klasu, tj. počtem zrn a jeho hmotností. To souvisí i s dynamikou uvolňování dusíku, která je nejvyšší v období tvorby generativních orgánů (v červnu). Odrůdy s vysokou produktivitou klasu se ukázaly jako vhodnější pro ekologické zemědělství.

Důkazem udržitelnosti systému je setrvale dobrá úroveň obsahu přijatelných živin v půdě.

Variační koeficient obsahu u jednotlivých živin je 10,2–19,5 %. Za celé období nedošlo ke snížení obsahu přijatelných živin, což znamená, že ekologický systém hospodaření neochuzoval půdu. Zdroje živin pocházejí z intenzivního zvětrávání, atmosférického spadu, mineralizace organické hmoty v půdě po předplodinách a symbiotické fixace dusíku jetelovin a luskovin.

ekologické zemědělství; výnos pšenice; struktura výnosu; produkční potenciál; udržitelný agroekosystém

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