FERTILIZER CONSUMPTION PATTERNS IN CENTRAL EUROPEAN COUNTRIES – EFFECT ON ACTUAL YIELD DEVELOPMENT TRENDS IN 1986-2005 YEARS – A COMPARATIVE STUDY OF THE CZECH REPUBLIC AND POLAND

MODELE KONSUMPCJI NAWOZÓW MINERALNYCH W KRAJACH EUROPY CENTRALNEJ – WPŁYW NA TRENDY PLONÓW RZECZYWISTYCH W LATACH 1986-2005 – ANALIZA PORÓWNAWCZA REPUBLIKI CZESKIEJ I POLSKI

Witold GRZEBISZ[1], Jean DIATTA[1], Rolf HARDTER[2], Katarzyna CYNA[1]

[1]Department of Agricultural Chemistry, University of Life Sciences, 60-625, Poznań, Poland
tel. (+48) 61 848 77 88; fax: (+48) 61 848 77 87, e-mail: witegr@up.poznan.pl

[2]Kali and Salz Polska, Pl. Wiosny Ludów 2, 61-831 Poznań, Poland

Manuscript received: January 28, 2009; Reviewed: March 3, 2010; Accepted for publication: March 4, 2010

ABSTRACT

This study outlines the long-term trends of fertilizers consumption in the Czech Republic and Poland and their impact on actual yield development of main crops for the period 1986-2005. In both countries dynamics of N, P, K fertilizers use showed analogical trends. Based on amounts and nutrient ratio of consumed fertilizer, as expressed as P_2O_5:N and K_2O:N ratios, there were distinguished three phases of fertilizers use: i) high ii) collapse and iii) restoration/stagnation. The stagnation phase was attributed for P and K in the Czech Republic. The observed yield depressions since the 1990s reflect changes in farmer's long-term fertilization and has been termed a temporary yield gap (TYG). However, its long-term existence negatively affects crop production stability. The development of new, country specific strategies in the management of P and K, i.e. adopted to natural soil fertility conditions, is a main goal of present agriculture of both countries, compared in the presented study.

KEY WORDS: long-term patterns of fertilizer consumption, trends of actual yields development, temporary yield gap, the Czech Republic, Poland

STRESZCZENIE

Przeprowadzone badania przedstawiają długoterminowe trendy zużycia nawozów mineralnych w Republice Czeskiej i w Polsce oraz ich wpływ na trendy plonów rzeczywistych, roślin uprawnych w okresie 1986-2005. W obu krajach w tym okresie dynamika zużycia nawozów N, P i K przebiegała analogicznie. Na podstawie ilości stosowanych nawozów i ich struktury, przedstawionych jako stosunki P_2O_5:N i K_2O:N, wyróżniono trzy, zmienne w długości, fazy konsumpcji : i) dużej ii) załamanie, iii) restaurację/stagnację. Stan stagnacji odnotowano dla P i K tylko w Czechach. Depresję plonów roślin uprawnych, ujawnioną z początkiem lat 90-tych a odzwierciedlająca zmiany w strategii nawożenia, określono terminem tymczasowa redukcja plonów (TRP). Wieloletnia trwałość tego stanu wpływa jednak ujemnie na stabilność produkcji roślinnej. Budowa nowych strategii gospodarki P i K, dostosowanych do warunków naturalnych, to znaczy warunków naturalnej żyzności gleby, jest zatem głównym zadaniem obu porównywanych w tym opracowaniu krajów.

SŁOWA KLUCZOWE: dynamika zużycia nawozów, trendy plonów, tymczasowa redukcja plonów, Republika Czeska, Polska

STRESZCZENIE ROZSZERZONE

Badania nad określeniem trendów zużycia nawozów mineralnych i ich wpływu na plonowanie głównych grup roślin uprawnych w Republice Czeskiej i w Polsce przeprowadzono dla lat 1986-2005. Materiały źródłowe obejmowały (i) zużycie nawozów (IFADATA Statistics online), (ii) powierzchnię zasiewów i plony: zbóż ogółem, pszenicy, rzepaku, buraków cukrowych (FAO Yearbook, Production). Wybór państw testowych wynikał z oceny naturalnych warunków produkcji (tab. 1 i 2).

W obu krajach długoterminowe trendy zmiany ilości, jak i struktury zużycia nawozów, wyrażone jako stosunki P_2O_5:N i K_2O:N wykazały analogiczne prawidłowości. Na podstawie obu tych kryteriów wydzielono trzy okresy zużycia nawozów w badanym okresie: i) duże ii) załamanie, iii) restauracja/stagnacja. Stan stagnacji odnotowano dla P i K w Czechach (ryc. 1, 2, 3, 4, tab. 3). W obu krajach załamanie się rynku nawozowego wywarło głęboki, ujemny wpływ na wieloletnie trendy plonów głównych roślin uprawnych. Badane rośliny wykazały analogiczne tendencje, lecz o różnej długości, pozwalając wydzielić trzy wyraźnie zaznaczone, w chronologicznej kolejności, fazy poziomu plonowania roślin: (i) wysoki – lata 1986-1990 (ii) recesja – ujawniła się w latach 1991-1994, zmiennie dla grup roślin (iii) restauracja – od roku 1992/1993 do 2005 (ryc. 5, 6, 7, 8). Fazę 1 - przyjęto umownie za poziom standardowy plonów, a pojawiającą w kolejnych latach różnicę między plonem rzeczywistym a standardowym określono terminem tymczasowa redukcja plonu, (TRP). Stan ten odnotowano dla wszystkich grup roślin, lecz tylko dla buraków, spośród badanych gatunków, został przełamany po krótkotrwałej recesji (ryc. 8).

Pomimo, że naturalna żyzność gleb w Republice Czeskiej jest zdecydowanie większa niż w Polsce (tab. 1), poza burakami cukrowymi, w tym kraju nie odnotowano istotnego wzrostu plonów, likwidującego TRP. Podstawową przyczyną tego stanu są bardzo duże, sezonowe wahania plonów, wynikające pośrednio ze złej struktury stosowanych nawozów, na co wskazuje bardzo szeroki stosunek P_2O_5:N i K_2O:N.

Obecny poziom produkcji głównych roślin uprawnych wskazuje na wieloletnią stagnację plonów w Republice Czeskiej. W Polsce zachodzi natomiast powolna restauracja plonów w stosunku do poziomu z końca lat 80-tych, lecz pomimo pozytywnych trendów, plony realne kształtują się na poziomie umiarkowanie niskim. Dalszy ich wzrost wymaga dokonania strategicznych zmian w gospodarce nawozowej, odniesionych nie tylko do ilości, lecz głównie do struktury stosowanych nawozów (zawężenie stosunku P_2O_5:N i K_2O:N). Jakiekolwiek działania naprawcze podejmowane w każdym z badanych krajów, winny uwzględniać lokalną – krajową, specyfikę produkcji roślinnej, wynikająca z różnic w naturalnej żyzności gleb uprawnych. W Republice Czeskiej wskazanym byłoby podjęcie działań zwiększających udział rezerw glebowych podstawowych składników mineralnych w zaopatrzeniu uprawianych roślin, zwłaszcza w potas. Przeprowadzone studia mogą służyć jako wartościowe dane referencyjne, przydatne dla analityków i decydentów na rynku rolniczym, i to nie tylko w Republice Czeskiej, lecz także w pozostałych krajach Europy Centralnej.

INTRODUCTION

It is clearly recognized at present, that further food production meeting the steadily raising world demand will increasingly depend on the contribution by crop yield improvement mainly in the farming areas of temperate regions, including Central European (CE) countries [6, 17]. This region, which has always been an important production base for major agricultural crops, went through dramatic political and economic changes at the beginning of the 1990. Within a short period of time the attempt was undertaken to transform these countries from centrally planned in market oriented economies with consequence on all sectors of the economy, especially on agriculture. Until the end of 1980s agriculture of all countries of the CE was strongly supported by state subsidies. One of the most important forms of subsidies was a significantly reduced price for fertilizers and lime. The political change at beginning of the 1990s caused a sudden cut of subsidies and a drastic increase of prices for all means of production [8, 13, 15].

The main objective of this paper is to describe the period after the collapse of the previous, fertilizer subsidy driven situation until today in different phases, characterizing the fertilization practices that followed. The second objective is to assess the impact of fertilizers consumption patterns on actual yields of major crops development.

MATERIALS AND METHODS

Part I. General characteristics of the Czech Republic and Poland agriculture

According to FAO, the Czech Republic (acronym used in figures – CZ)and Poland (PL) belong to Central Europe (CE). Poland is located on the north side and the Czech Republic on south side of Sudety mountains. The separation of both countries by the Sudety mountains is an important geographic feature, due to the fact that it is a borderline for both soils and climate. About 2 million years ago, glacial deposits covered the area north of this

mountain range, the territory of Poland, whereas south of it, the territory of the Czech Republic consisted of relict deposits of the permafrost zone [16]. As a result basic soil fertility characteristics differ to a large extent [9]. In the first place this relates to the textural composition, decisive for inherent soil fertility and buffer capacity. In Czech Republic 75% of the soils consist of loams, clays and loess, whereas these textural soil classes in Poland together share only 30,5% of the total soils area (Table 1).

As a result of geography, agriculture of the two countries in terms of farm structure as well in potential production shows distinct differences. Nevertheless a common feature is that in both countries the largest area of arable land is allocated to cereals. In 2005, the area under cereals covered 61% of the arable land in the Czech Republic and 81% in Poland [7]. In the Czech Republic cereal production is dominated by wheat and barley, whereas in Poland by wheat and rye [4, 5, 7] (Table 2). Crops of second importance after cereals are oilseed rape and sugar beet, among all crops, which have been also included in this study.

Part II. Sources of statistical data and analytical methods

The main sources of statistical data, referring to agriculture production in the period 1986-2005 were FAO Statistical yearbooks, division Production [5], Eurostat 2007 statistical yearbooks, online versions [4]. The fertilizers consumption data refer to the IFA databank [12]. Fertilizer consumption per ha was calculated by dividing total consumption of N, P, K by the actual harvested area (not by the total arable area) in the respective year [5]. Therefore, calculated values in this paper may deviate from data published elsewhere, presenting higher but at the same more reliable assessment of fertilizer use.

Most regressions reported in the current paper are linear, but some quadratic models were also applied. The accuracy of the quadratic models-based data was estimated as reported below:

$$SE = \left[\sum (M_D - C_D)^2 / (X - 2)\right]^{1/2} \quad [1]$$

where, SE, M_D and C_D, are the standard error of estimate, measured and calculated data, respectively, X is the number of data [18].

RESULTS

Part I. Trends in fertilizers consumption

Poland and the Czech Republic experienced a very similar collapse in the fertilizer consumption during the first stages of the transition from centrally planned to market economies. In the period lasting from 1986 to 2005 consumption of N, P, K fertilizers in all CE countries had undergone big changes with respect to:

1. The total amounts of fertilizers applied per ha;
2. The ratios in which nutrients were applied, i.e. P_2O_5:N and K_2O:N, etc.

The general trend of N, P, K fertilizers consumption (Y)

Table 1. The main soil textural classes, % of total country area[1]

Soil textural classes	The Czech Republic	Poland
Loose/slightly loamy sands	3	35
Loamy sands	7	10
Light loams	15	16
Medium and heavy loams	28	10
Clays	13	1
Loess	19	3,5

[1]Grzebisz, Fotyma (2007)

Table 2. The general overview of the Czech Republic and Poland agriculture[1]

Main characteristics		The Czech Republic	Poland
Arable land, ha · 1000		3 082	13 993
Area under main crops, ha · 1000:			
(i)	total cereals	1 651	8 814
(ii)	oilseed rape	324	437
(iii)	potatoes	69	1 251
(iv)	sugar beets	59	333
(v)	winter wheat	973	2 635

[1]FAO Statistical yearbooks 2005/06, vol. 2;

Table 3. The nutrients consumption structure for selected years[1]

Fertilizer consumption	Years		
	1988	1992	2000
	The Czech Republic		
P_2O_5:N	0,73	0,27	0,17
K_2O:N	0,73	0,13	0,09
	Poland		
P_2O_5:N	0,59	0,34	0,30
K_2O:N	0,67	0,41	0,41

[1]based on the Figs. 3 and 4

over the studied period (CY – consecutive years, 1986 = 1) is almost the same for the Czech Republic and Poland and fits the best the quadrate regression model:

Czech Republic:

Nitrogen: $Y = 0.55CY^2 – 12.9CY + 148.8$; $R^2 = 0.60$; [2]
SE = 19.3 (14.4 – 31.9); n = 20

Phosphorus: $Y = 0.58CY^2 – 16.7CY + 125.8$ $R^2 = 0.86$; [3]
SE = 6.6 (0.4 – 25.6); n = 20

Potassium: $Y = 0.66\ CY^2 – 18.6CY + 132.3$; $R^2 = 0.88$; [4]
SE = 6.9 (0.4 – 26.7); n = 20

Poland:

Nitrogen: $Y = 0.37CY^2 – 8.57CY + 105.8$; $R^2 = 0.46$; [5]
SE = 13.8 (10.4 – 22.8); n = 20

Phosphorus: $Y = 0.37\ CY^2 – 9.45CY + 75.2$; $R^2 = 0.72$; [6]
SE = 4.4 (0.3 – 15.3); n = 20

Potassium: $Y = 0.42\ CY^2 – 10.97CY + 90.1$; $R^2 = 0.81$; [7]
SE = 5.9 (1.1 – 18.5); n = 20

where, SE expresses the mean standard error of estimate for the range in the parenthesis, (kg · ha^{-1}).

However, these functions, in spite of their mathematical reliability, do not reflect real trends over the studied period. The general trend of N, P, K fertilizers consumption over the studied period is similar for the Czech Republic and Poland (Fig. 1, Fig. 2). Based on the separation of the fertilizer use trends the whole 20 years' period could be divided into three phases of different length according to the level total fertilizers consumption:

1. High level of use;
2. Collapse of use;
3. Stagnation/restoration of use.

The first phase represents the end of a very long period of high fertilizer consumption, which had begun in 1970s. The highest use of all major nutrients, i.e. N, P, K as well as lime was recorded in the last decade of the 1980s [8]. From 1986 - 1989, the average mineral N use was ca 125 and 100 kg ha^{-1} for the Czech Republic and Poland, respectively. During the same period, the consumption of mineral P amounted to 95 and 65 kg P_2O_5 ha^{-1}, respectively, whereas mineral K was used at the amounted of 100 and 80 kg K_2O ha^{-1}, in the Czech Republic and Poland, respectively.

The second phase is characterized by a steep decline in fertilizer use, with distinct differences regarding the duration of this period with respect to country and nutrient. In the Czech Republic, K consumption already declined between 1986 and 1991 at a rate of 10 kg K_2O ha^{-1}year^{-1}, dropping further from 70 kg K_2O ha^{-1} to ca 10 kg K_2O ha^{-1} in 1992. In Poland this negative trend in K consumption was first noted between 1987 and 1989 and was followed by a steep decline until 1992, when K consumption has dropped to 20 kg K_2O ha^{-1}. The consumption of phosphorus fertilizers showed in both countries very similar trends. In 1990 and 1991 the use of P fertilizers declined from above 95 to below 20 kg P_2O_5 ha^{-1} in the Czech Republic and from 65 to ca 10 kg P_2O_5 ha^{-1} in Poland. In case of nitrogen, the decline in use was more dramatic in Poland than in the Czech Republic. In Poland, N consumption suddenly dropped from 100 kg N ha^{-1} to below 50 kg N ha^{-1} in 1990 and finally to 40 kg N ha^{-1} in 1991. In the Czech Republic the first drastic decline in N consumption was noted one year later, in 1991 reaching the level of 60 N ha^{-1}.

The third phase, which for both countries began in 1993 shows a recovery in mineral fertilizer use, with distinct differences between these two countries and specific nutrients. Whereas in the Czech Republic only the use of nitrogen was improved and P - as well as K - use stagnated, in Poland, also these two nutrients benefited from this positive consumption trend, though to a much lesser degree. Today in the Czech Republic N consumption has stabilized at a level of approx 100 kg ha^{-1}, amounting to 80% of the level before the collapse. During the third phase, in Poland the consumption of N fertilizers increased to 70 kg ha^{-1} year^{-1}, an amount that is stable since 2003. On the other hand, the consumption of P and K increased at a rate of 0.8 kg ha^{-1} y^{-1} and reached

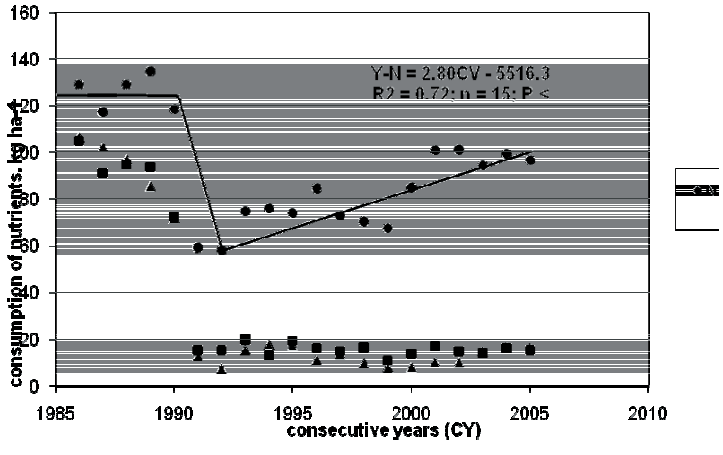

Fig. 1: Trends in fertilizers consumption in the Czech Republic for the period 1986-2005

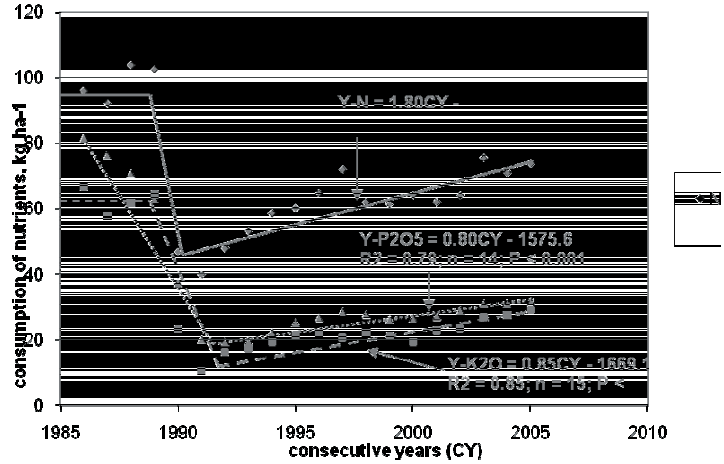

Fig. 2: Trends in fertilizers consumption in Poland for the period 1986-2005

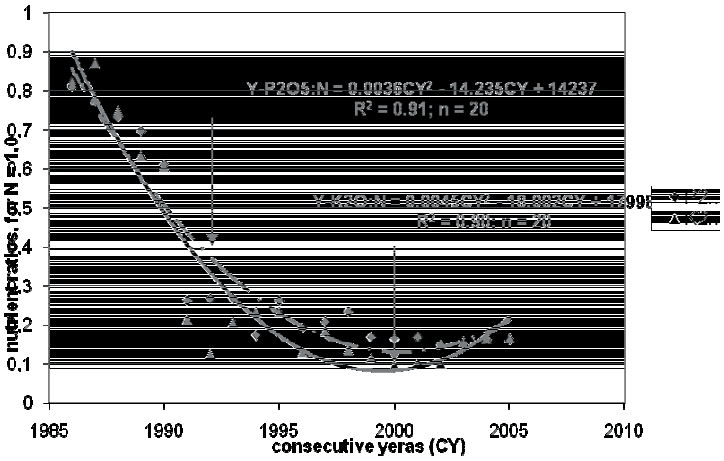

Fig. 3: General trends of nutrient ratios in main fertilizers, the Czech Republic, (1986-2005)

29 kg P_2O_5 and 32 kg K_2O ha^{-1} by 2005.

The second fertilizer consumption characteristics refers to structure of nitrogen and other main nutrients use, i.e. P_2O_5:N and K_2O:N ratios. The quadrate regression model best describes the found time course trends of these two relationships as presented in Figs. 3 and 4.

The above-presented figures and concomitant equations clearly indicate that in the period 1986-2005 relationships between amounts of main nutrients applied have undergone manifold change. The main reasons of these changes were (i) variable annual rates of nitrogen consumption (ii) tendency of strong decrease of phosphorus and potassium fertilizers use. In Table 3 data describing the relationships between the nutrients in the main phases of nutrients use are shown. In the Czech Republic the declining trends for both relationships ended for phosphorus at the end of 1990s and for potassium in 2002. At present both relationships are extremely wide, even below 1:0.1 for the K_2O:N relationship. In Poland the same trends were recorded, however since 2000 they have become much wider, even reaching 0.3:1 for P_2O_5: N and exceeding 0:0.4 for K_2O:N ratios.

Part II. Crop yield development trends

The above-evaluated patterns of fertilizers consumption are general feature of the whole region [9]. The interesting question that follows the above developments in fertilizer consumption was, how did those affect crop production during the studied period. Therefore statistical data on actual yields for the most important crops were analyzed and trends of crop yield development were calculated.

In the growing seasons from 1991 to 1994, yields of cereals and oil-seed rape have sharply decreased, reaching the lowest values. Since that period a slight recovery is observed, but yield increments depended on the respective crop and country.

Total cereals

Cereals, covering the largest area in both countries, showed three distinct phases of yields trends over the period 1986 - 2005 which can be described as:

1. Actual-standard yield (ASY);
2. Yield recession (YR);
3. Yield recovery/ Yield stagnation (YR/YS).

At the end of 1980s yields of total cereals had increased significantly and in both countries they reached the highest levels in 1990, in spite of the fact that fertilizer consumption was already slightly reduced at this time (Fig. 5). Since nutrient supply over the years was constant, yield fluctuations between years during the period of abundant nutrient use (1980-1990) suggest that annual yields were limited by other factors than nutrients, in particular by water shortage. During this period the average grain yields amounted to 4.77 t ha^{-1} and 3.11 t ha^{-1}, in the the Czech Republic and Poland, respectively. In order to make assessment of long-term yield variability, these averages were taken in this study as the actual-standard yield (ASY). It is highly surprisingly that these averages were not topped in the following years, with the exception of 2004, which due to favorable meteorological conditions (sufficient and well distributed precipitation), farmers in both countries recorded exceptional cereal yields [5].

The second yield development phase, defined as a yield recession phase (YR), shows distinct differences between the two countries. In the Czech Republic this phase started in 1992 and ended in 1994. The average yields during this phase amounted to 4.06 t grain ha^{-1}, which means only 82% of the ASY. In Poland the yield decline was much more expressed but this recession phase lasted only one growing season. In the course of 1991 and 1992 growing seasons yields of total cereals decreased by 0.70 t ha^{-1}, reaching 75% of the ASY.

The observed recession of actual yield fallowing the sudden decline in N, P, K fertilizer use has been therefore termed the temporary yield gap (TYG). There might be two major reasons of its appearance:

a. the reduction in fertilizers use, including nitrogen since 1990;

b. the concomitant water shortage, which reduced water and soil nutrient availability;

c. low accessibility of actually grown plant crops to the past accumulated P, K resources.

The third phase, which is termed yield recovery and/ or yield stagnation as defined based on the obtained linear trends. It was generally assumed, that the year of the lowest yield is the beginning of this phase. On the average, in the Czech Republic yearly yield increase was slightly higher than in Poland, amounting to 60 kg ha^{-1} y^{-1}, but until 2005 the TYG has not been closed. This fact is an indirect result of increasing dependence of cereals yield performance on external factors, which influence the nutrient supply to crops, for example water availability. In Poland yearly yield increments during this phase were slightly less compared to Czech Republic, but consistent, amounting to 52 kg ha^{-1} y^{-1}. Therefore, Poland in contrast to its neighbor was, however able to overcome the TYG, that developed during the recession phase, already in 2000.

Winter wheat

Long-term patterns of wheat yields are almost the same as found for total cereals (Fig. 6). The ASY levels for the Czech Republic and Poland were at 5.06 and 3,74 t ha^{-1}, respectively. However, in the weather favorable 2004

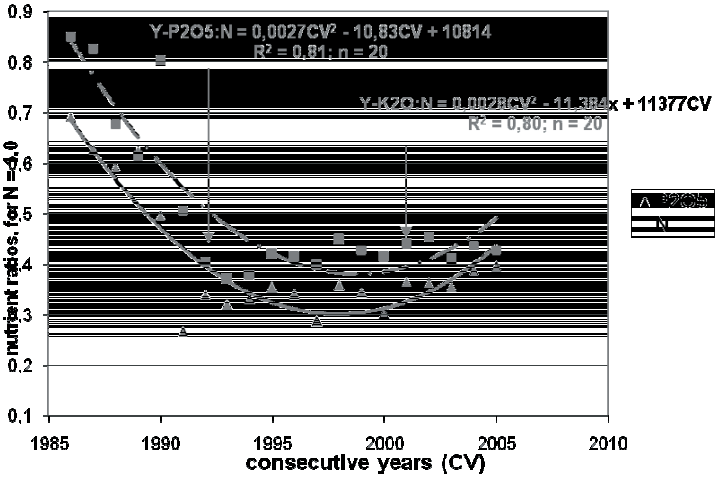

Fig. 4: General trends of nutrient ratios in main fertilizers, Poland (1986-2005)

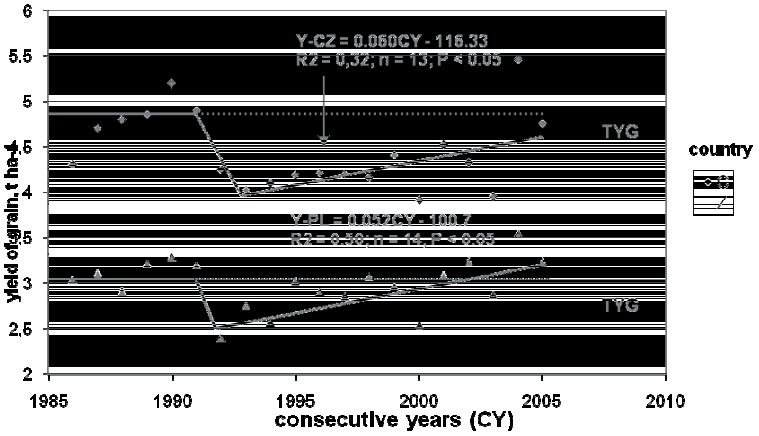

Fig. 5: Trends in total cereals production in the period 1986-2005

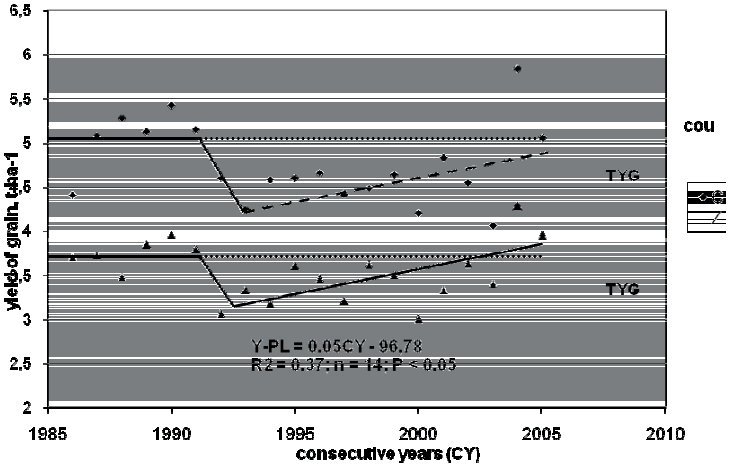

Fig. 6: Trends in winter wheat production in the period 1986-2005

winter wheat yielded much higher amounting to 5,84 and 4,28 t ha^{-1}, respectively. The observed TYGs are high but slightly lower than those found for cereals, resulting in production of wheat on much more fertile soils than other cereals. Yield trends, for both countries in the third phase represent different patterns. In the Czech Republic, the yield increase since 1993 is insignificant, and yields are characterized by high year-to-year variability. Therefore, it would be better to define this period lasting until today, as the stagnation phase. Quite different yield trends were found in Poland. During the favorable year 2004 the TYG in Poland was overcome.

Oil-seed rape

Trends in oilseed rape yields are very similar to those presented for cereals (Fig. 7). Therefore the same phases of yield performance have been established. In the first phase, which in both countries ended in 1989, the yield averages for the period 1986-1990 amounted to 2.80 and 2.40 t ha^{-1} for the Czech Republic and Poland, respectively. In 2004 the national averages were 3.6 and 3.0 t ha^{-1}, respectively. These both sets of data show much smaller differences between the studied countries. In addition they are almost the same as found for winter wheat, which naturally follows oilseed rape in the classical crop rotation.

The recession phase began in 1991 in both countries and ended in 1992 in the Czech Republic but one year later in Poland. The lowest yields were harvested in two consecutive years, i.e., 1992 and 1993. The national average for these two years amounted to 2.21 and 1.76 t seeds ha^{-1} for the Czech Republic and Poland, respectively. In comparison to the ASY, the relative TYG in Poland

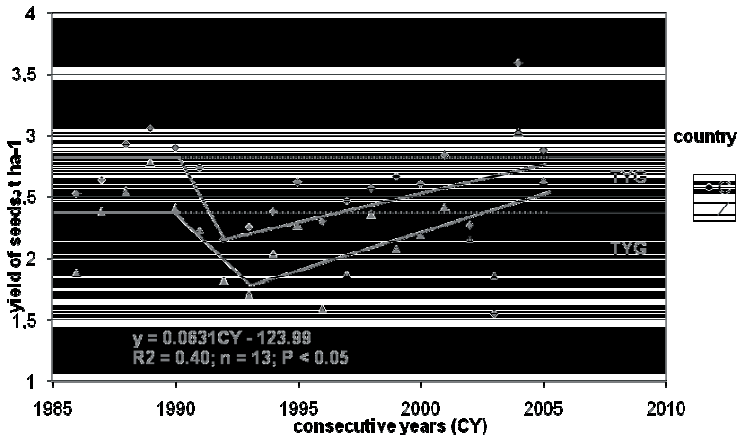

Fig. 7: Trends in rape seeds production in the period 1986-200

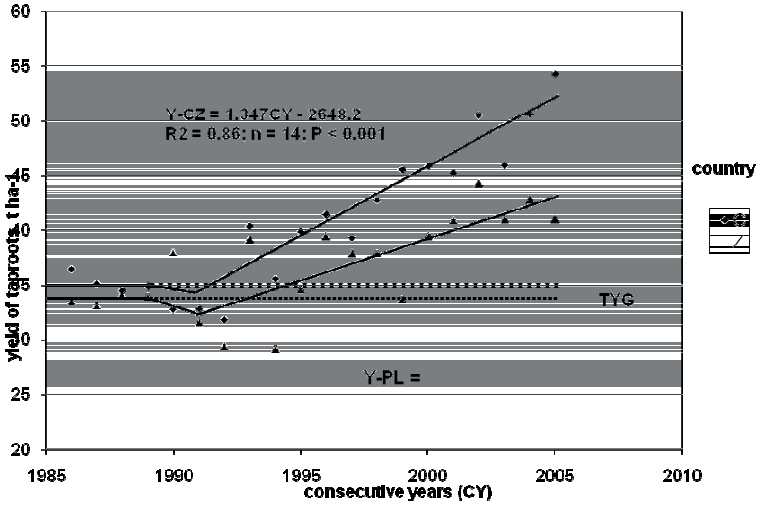

Fig. 8: Trends in sugar beet production in the period 1986-2005

was 34% while in the Czech Republic only 24%. The third period, i.e. recovery phase has begun since 1994. In the Czech Republic due to increasing seasonal yield variability the TYG has not been fulfilled up to 2005. In Poland, as a result of the positive and constant yield trends, which has been statistically corroborated, the yield depression has been overcome in 2004.

Sugar beet

Since sugar beet is very sensitive to variations in nutrient availability, therefore yields of this crop are ideal indicators for soil quality assessment. As presented in the Fig. 8, at the end of the 80s, the yields of taproots were generally low, ca 35 t ha^{-1}. As in the case of other crops, the yield recession phase can also be distinguished. The Czech Republic was first to experience this yield decline, and this phase lasted three years, whereas only two years in Poland. In the yield recovery period 1993 - 2005 the annual yield increase in the Czech Republic amounted to ca 1.40 t ha^{-1} y^{-1} and Poland to 0.82 t ha^{-1} $year^{-1}$. The main reasons for the continued and high yield increase are a systematic reduction of sugar beet area sown in the less favorable soils. During the third phase, the area under sugar beet declined from more than 100 000 ha in 1986 to less than 70 000 ha in 2005 in the Czech Republic and in Poland from more than 420 000 ha to less than 286 000 ha in 2005 [5].

DISCUSSION

The presented elaborated statistical data are very good example as how deeply crop production in the Central European countries has become dependent on fertilizer application during the last 5 decades. Two sets of data, i.e. the Actual-Standard Yield and yields harvested in 2004, clearly explain why, the average yields harvested in both countries respond more to soil fertility level, achieved through previous fertilization practice, than to currently applied fertilizers. This thesis corroborates findings of Haberle and Mikyskova [10] who conducted a study on winter wheat and spring barley productivity in the Czech Republic districts in years 1993-2001. According to those authors consumption of fertilizers explained 70% of yields variability. This thesis is also corroborated by data sets presented for total cereals and especially for oilseed rape. Grain and seeds production, in spite of higher natural soil productivity in the Czech Republic, shows high year to year variability and permanent existence of temporary yield gaps (TYGs). It is highly surprising that consumption of nitrogen in the Czech Republic, especially, has increased in the first years of the XX century without any farmer's efforts supporting its efficiency. In Poland, in spite of generally lower yields, P_2O_5:N and K_2O:N relations are much narrower, therefore the TYGs of the studied crops are also lower, but yields of main crop are low. Therefore, the FAO projections of in winter wheat yields increase in 2030 are likely to be fulfilled in both, the Czech Republic and in Poland [6]. In the case of Poland the main limiting factor is related to much worse in comparison to the Czech Republic natural conditions, i.e. soils fertility level and amounts of precipitation.

The conducted study clearly revealed that the Czech Republic and Poland differing completely in soil fertility characteristics have to develop distinct methods for improving yields of main crops. This means that not only the amount and structure of applied fertilizers needs to be adjusted but it also necessary to take into account the growing crop accessibility to soil nutrient pools. This case is addressed directly to soils in the Czech Republic, which are naturally fertile and in turn their potential productivity should perform at much higher level. However, at present in the Czech Republic processes of soil mining in the upper part of the soil profile with respect to P and K are highly advanced, as indicated by very fast decrease of soils rich in both nutrients and long-term negative balance for potassium [2, 11].

It is well known, the plant crop accessibility to soil nutrient pool is inherently related to conditions of root system growth in the soil body. The main problem for farmers is to increase soil volume directly occupied by plant roots. There might be suggested at least, three main areas of soil productivity improvement, i.e. through increasing plant crops accessibility to nutrients present in the subsoil: (i) regulation of soil reaction (ii) increase of organic matter content (iii) removing of any kind of hardpans [1, 9, 14]. It seems highly probable that in the case of Poland all of these three groups of measures are of primary importance. In the case of the Czech Republic the second and the third group should be treated with great attention.

FINAL CONCLUSIONS

Poland and the Czech Republic due to differences mainly in the inherent soil fertility showed distinct differences in yield response to nutrient omission which also caused that fertilizer management following this initial period of collapse varied to a large extent until the present time.

At present, crop production both focus a strong fluctuation cereal and oilseed rape yields between years and a yield stagnation over the years in the Czech Republic and only slight increase in Poland. The main reason for these observations is the widening of P_2O_5:N and K_2O:N fertilizer consumption ratios in 1993-2005 years.

Therefore, the main goal of agriculture and economics of the country is to achieve yield stabilization over time. Its realization requires efforts to change practices in two areas: (i) amounts and structure of applied fertilizer (ii) build-up conditions for plant accessibility to nutrients present in deeper soil layers. The suggested management options should be introduced simultaneously.

This study may serve as a valuable reference for agricultural analysts and decision makers not only for the Czech Republic and Poland but also for most of the Central European countries.

REFERENCES

[1] Atkinson D., Black K.E., Dawson L.A., Dunsiger Z., Watson C.A., Wilson S.A., Prospects, advantages and limitations of future crop production systems dependent upon the management processes, Ann. Appl. Biol. (2005), 146: 203-215.

[2] Cermak, P., Nutrient consumption in the Czech Agriculture in relation to current status of soil properties, Proceedings: Plant nutrition and its prospects. Brno, 5-6 September 2007, pp. 125-128.

[3] Cochrane N., EU Enlargement: Implications for U.S._EU agricultural relations, U.S.-U Food and Agriculture Comaprison/WRS-04-04 (2004), pp. 78-86.

[4] European Commission, Eurostat 2007, Agriculture, Main Statistics 2005-2006.

[5] FAO, Statistical Yearbook, Rome, 1989, 1991, 1994, 1997, 2000, 2004, 2006.

[6] FAO, Fertilizer requirements in 2015 and 2030 revisited, FAO, Rome, 2004.

[7] FAO, Statistical Yearbook 2005/06. Vol. 1 and 2, Rome, 2007.

[8] Fotyma M., Fertilizer use by crop in Poland. FAO, Rome, 2003, pp.

[9] Grzebisz W., Fotyma M.,. Recommendations and use of potassium fertilizers In Central-Eastern Europe (CEE). The International Fertiliser Society (2007) Paper No. 621.

[10] Haberle J. and Mikyskova J., Relation of cereals yields and variability to soil-climate and production characteristics of districts of the Czech Republic, J. Cent. Eur. Agric. (2006) 7(4): 661-668.

[11] Hlusek, J., Klir, J. and Balik J., The current situation in plant nutrition and fertilization in CR, Proceedings: Plant nutrition and its prospects. Brno, 5-6 September 2007, pp. 15-22.

[12] IFADATA Statistics online. www.fertilizer.org/ifa/statistics/ifadata/dataline.asp, 14.11.2007

[13] Kelch, D. and Osborne, S., Crop production capacity in Europe. Economic Research Service/USDA, Agricultural Outlook (2001) 3: 19-23.

[14] Milford G., Armstrong M., Jarvis P., Houghton B., Bellett-Travers D., Jones J., Leigh R., Effect of potassium fertilizer on the yield, quality and potassium off-take of sugar beet crops grown on soil of different potassium status. J. Agric. Sci., (2000) 135: 1-10.

[15] Pacák B., Possibilities of Agricultural Production in the Czech Republic, (2006), www.jantzendevelopment.dk/Portals/3/CzechRepublic

[16] Plant, J., Whittaker, A., Demetriades, A., De Vivo, B., Lexa, J., The geological and tectonic framework of Europe. in: Ed. Salminen, R. (Ed.), Geochemical Atlas of Europe. Part 1. Background Information, Methodology, Maps. GTK, FOREGS, 2005.

[17] The European Commission, Prospects for agriculture markets in the CEECs. CAP Reports, 2000: ec.europa.eau/agriculture/publi/caprep/prospects2000__

[18] Steel, R., Torrie, J., Principles and procedures of statistics, Mc Graw-Hill, New York, 1960.