SCIENTIFIC INFORMATION

Economic balance of mineral nutrients in Czech agriculture in 1996–2000

Ekonomická bilance minerálních hnojiv v českém zemědělství v letech 1996–2000

J. VOSTAL

Czech University of Agriculture, Prague, Czech Republic

INTRODUCTION

The main task of plant nutrition and fertilisation is to study the turnover of compounds and nutrients in agriculture, to influence chemical processes in soils and plants, which can influence the production and quality of plants. The aim of this study is sustaining the soil fertility, i.e. suitable conditions of plant growth and development. Without any exaggeration, it is possible to state, that it would be impossible to fulfil the foregoing intentions without balancing plant nutrition and it has been important in all types of agricultural technologies – traditional, integrated, ecological, biological etc. Differences may result more likely from the philosophical point of view belonging to a special aspect.

This contribution follows the previous published communication (Vostal 1997), which shows, that it is not possible to keep up the previous yielding level without a satisfactory supplement of nutrients drawn by the harvested products, for the even soil fertility is decreasing at the negative nutrient balance. This contribution is the proof of the development of the situation in the five years period of 1996–2000.

LITERATURE REVIEW

The nutrient balance has been the basis for nutrient doses projection in most countries. Besides that, it is possible to evaluate the used intensity of fertilisation on soil properties, as one of the factors substantially influencing soil fertility. Many scientific results from the last period have proven these facts, dealing with the national or regional balance (Bach, Frede 1997; Gorbanov, Gorbanova 1998; Götz, Zenthner 1997; Uebel 1999; Weiser, Hartl 1997 and others), or the balances on experimental plots (Albert, Lippold 1997; Hösch et al. 1997; Klír et al. 1995 and others). Klír's study (1999) is very interesting in the comparison of nitrogen balance development in 19 European countries in 1985, 1990, 1995 and 1997. A general trend of the decrease of mineral nutrients consumption is evident, but the fall noticed in the former post-communist countries was substantially higher in comparison with other countries. The 1997/1985 index of nitrogen in mineral fertilisers in the CR is 54%, in Hungary 39% and in Poland 63%. If the decrease of farm animals in the same period is included, then these countries showed, with regard to the manure produced, 63% decrease in the CR and in Poland and 55% in Hungary, in comparison with the initial position. Situation in other nutrients is more critical and their balances have been negative since 1991. Then it is clearly evident, that the gross crop production (CZK per 1 ha of farm land) decreased in our country from 10 487 in 1990 (Statistická ročenka 1998) to 8 101 CZK in 1995 (Vostal, Rosochatecká 2000).

METHODS

The process of balancing was substantially the same as in the previous contribution (Vostal 1997). The data about harvested areas and yields were taken over from the Yearbooks of the Czech Statistical Office (Definite data about crop yields in the Czech Republic; CR in 1996–2000), the nutrient consumption in mineral fertilisers provided by the Czech Ministry of Agriculture – Department of Farm Commodities and the data about livestock units per l ha of agricultural land were taken over from the Statistical Yearbook 2000.

The change concerned the balance of the harvested by-product quantity. We took account of the fact that the above-ground green mass of root crops is mostly not harvested, with the exception of desiccation purposes, and also the straw of grain leguminous crops and maize grown for grain is not harvested and about 40% of the cereals straw is not used and is mostly ploughed in. These matters most substantially influenced the nitrogen, potassium and partly calcium intakes by the harvested products.

RESULTS AND DISCUSSION

The development of economic balance is given in Table 1. It informs about the partial items in the individual years of the period 1996–2000 and it mentions also the previous evaluation cycles. As orientation data, it is necessary to consider the data about the quantity of mineral fertilisers concerning magnesium and calcium. At the

Table 1. Economic nutrient balance kg per ha of agricultural land in CR in 1996–2000

Nutrient	Period/Year	Mineral-fertilizers	Manure fertilizers	Symbiotic N fixation	Output by harvest	Balance[xx] ±
Nitrogen (N)	1986–1990	95.0	40.5	24.9	120.5	+39.9
	1991–1995	49.3	29.9	15.8	105.2	–10.2
	1996	61.3	25.3	17.6	94.5	+9.7
	1997	55.1	23.9	16.4	91.7	+3.7
	1998	53.3	23.5	13.9	86.5	+4.2
	1999	51.1	22.3	13.8	89.8	–2.6
	2000	58.9	21.3	13.8	84.1	+9.9
	1996–2000	55.9	23.3	15.1	89.3	+5.0
Phosphorus (P)	1986–1990	28.8	10.6		21.6	+17.8
	1991–1995	5.3	7.8		19.2	–6.0
	1996	5.1	6.6		16.6	–4.9
	1997	5.1	6.2		16.0	–4.7
	1998	5.5	6.1		15.3	–3.7
	1999	3.8	5.8		15.9	–6.3
	2000	4.7	5.5		14.9	–4.7
	1996–2000	4.8	6.0		15.7	–4.9
Potassium (K)	1986–1990	52.7	51.1		95.2	+8.6
	1991–1995	8.8	32.8		84.0	–42.4
	1996	6.6	27.9		66.6	–32.1
	1997	8.4	26.3		56.2	–21.5
	1998	6.1	25.9		58.6	–26.6
	1999	4.9	24.5		60.6	–31.2
	2000	5.1	23.5		56.0	–27.4
	1996–2000	6.2	25.6		59.6	–27.8
Magnesium[x] (Mg)	1986–1990	21.1	7.3		14.5	+13.9
	1991–1995	2.4	5.4		12.3	–4.5
	1996	2.1	4.6		9.4	–2.7
	1997	1.6	4.3		8.9	–3.0
	1998	1.5	4.2		8.2	–2.5
	1999	1.5	4.0		8.5	–3.0
	2000	1.5	3.8		8.1	–2.8
	1996–2000	1.6	4.2		8.6	–2.8
Calcium[x] (Ca)	1986–1990	231.7	25.8		27.8	
	1991–1995	33.2	19.0		24.4	
	1996	34.0	16.2		22.1	
	1997	25.0	15.3		20.2	
	1998	25.0	15.1		18.9	
	1999	25.0	14.3		19.4	
	2000	25.0	13.6		17.8	
	1996–2000	27.0	14.9		19.7	

[x] just the quantity given in calcium fertilizers

[xx] gross balance without further passive items, mainly losses (especially N denitrification) and therefore N consumption should be by 20–25 kg/ha higher

present time, the quantity of consumed magnesium fertilisers is not studied as well as the assortment of the used fertilisers. In calcium fertilisers, only the quantity of calcium matter used in agricultural production has been studied on the government level. Therefore, the data concerning these two nutrients need to be considered as not very accurate.

Table 2. Development of crop and yield structure in the CR (1990 = 100%)

Crops	Yield 1990 (t per ha)	Sown area		Yields per ha	
		1991–1995	1996–2000	1991–1995	1996–2000
Cereals (total) – grain	5.46	98.0	99.8	78.2	75.3
Leguminous crops	2.71	137.6	88.4	89.7	85.7
Potatoes	16.06	88.0	67.9	114.9	127.6
Technical sugar beet	35.03	90.4	67.3	106.3	127.1
Winter rapeseed	2.90	166.0	264.7	83.9	87.0
Maize for mass and ensilage	27.62	78.7	63.8	111.8	119.7
Perennial fodder crops (hay)	9.04	101.9	89.6	82.8	68.7
Meadows (hay)	4.89	115.0	132.1	76.8	68.1
Pastures (hay)	3.28	109.5	125.4	93.5	71.7

Table 3. Categories of AST on arable land and PGS in the CR in 1990/1992–1993/1998 and their development (%)

Item[2]	Category	% of category representation					
		arable land			PGS[1]		
		1990–1992	1993–1998	±	1990–1992	1993–1998	±
pH/KCl	till 4.5	1.2	2.0	+0.8	6.8	25.6	+18.8
	4.6–5.0	4.2	5.6	+1.4	10.7	25.3	+14.6
	5.1–5.5	14.6	19.3	+4.7	14.6	19.3	+4.7
	5.6–6.5	36.6	41.4	+4.8	37.5	18.6	–18.9
	above 6.6	48.3	39.5	–8.8	30.3	11.1	–19.2
mg P/kg	VN – very low	2.2	7.0	+6.8	22.5	19.7	–2.8
	N – low	10.4	17.6	+7.2	18.2	14.2	–4.0
	VH – suitable	39.4	32.0	–7.4	15.8	13.4	–2.4
	D – good	14.2	20.5	+6.3	10.3	19.3	+9.0
	V – high	28.6	12.3	–16.3	21.7	12.2	–9.5
	VV – very high	5.2	10.6	+5.4	11.5	21.2	+9.7
mg K/kg	VN – very low	0.9	1.9	+1.0	4.9	9.6	+4.7
	N – low	7.8	12.0	+4.2	17.6	21.0	+3.4
	VH – suitable	29.2	34.2	+5.2	23.9	24.2	+0.3
	D – good	36.3	32.9	–3.4	21.6	19.1	–2.5
	V – high	17.6	12.0	–5.6	16.2	13.4	–2.8
	VV – very high	8.2	7.0	–1.2	15.8	12.7	–3.1
mg Mg/kg	VN – very low	0.7	4.4	+ 3.7	0.7	3.4	+2.7
	N – low	6.3	20.0	+15.7	4.5	7.4	+2.9
	VH – suitable	28.2	29.3	+1.1	19.4	17.0	–2.4
	D – good	33.8	24.0	–9.8	30.9	18.8	–12.1
	V – high	17.8	12.9	–4.9	23.3	23.9	0.6
	VV – very high	13.2	9.4	–3.8	21.2	29.5	8.3

1 = Perennial grass stands (meadows and pastures)
2 = Mehlich II method, in cycle 1990–1992, 467 124 samples of farm soil and in the period 1993–1998, 308 663 samples were analysed

Source: Výsledky agrochemického zkoušení půd (1993, 2000 – revised)

Table 4. Mean values of the AST on arable land at PGS in the CR in period 1990–1992/1993–1998

Cycle	Mean values in CR – arable land				Mean values in CR – PGS			
	pH/KCl	mg P/kg	mg K/kg	mg Mg/kg	pH/KCl	mg P/kg	mg K/kg	mg Mg/kg
1990–1992	6.4	84	251	167	5.9	58	194	199
1993–1998	6.3	80	225	166	5.8	57	172	202
±	–0.1	–4	–26	–1	–0.1	–1	–22	+ 3

From the survey, it is evident, that the consumption of nitrogen fertilisers slightly increased after the lapse of five years (from 49.3 in the cycle 1991–1995 to 55.9 kg), but the mean consumption of phosphorus and potassium fertilises continually decreased (substantial annual variation was observed). The decrease in the number of farm animals has been continuing and it causes a lower production of all observed nutrients. According to the data of the CSO (Statistická ročenka 2000), the number of livestock units (LU) per one hectare of agricultural land decreased from 0.51 in 1996 to 0.43 in 2000. As a consequence of the decrease in bred animals, the acreage of leguminous and clover crops decreased too (Table 2). A low care given to their production technologies reflects also in the yields of these crops.

Economic balance of phosphorus, potassium and obviously magnesium and calcium has been negative since the beginning of the 90ies. Intensity of fertilisation is low, biological potential of crops has been insufficiently exploited and the crops suitable for the market conditions have been predominantly fertilised. The question is very often in the extensive growth of gross production with an effort for a minimum of growing costs accompanied by the nutrient consumption from the soil reserve.

Table 3 shows that the level of fertilisation is closely connected with the Agrochemical Soil Test (AST), as a very important yielding character. Differences are visible between the fertile soil and perennial grasslands. Thanks to the limited consumption of mineral fertilisers and decreased supply of soil nutrients, the quota of soils in the categories of low and very low reserves in arable land increased by 14% in phosphorus, 5.2% in potassium and 19.4% in magnesium. Accordingly, with the exception of phosphorus reserves, the situation is similar in meadows and pastures. Due to the limited consumption of calcium fertilisers, an increased share appeared of the soils with the pH lower than 5.0. In arable land, the part of the soils with the pH content lower than 5.0 increased up to 33.4%. Table 4 practically proves that the agrochemical soil properties are growing worse in the CR as a whole. The available phosphorus and potassium main soil reserves are also decreasing.

CONCLUSION

Economic nutrient balance, including the quantity supplied by mineral and organic fertilisers in assets, increased in nitrogen by the symbiotic N from leguminous crops and in liabilities quantity exported by crop yields. In 1996–2000, the balance of nitrogen was slightly positive (in average +5.0 kg per year) and it was negative in phosphorus, potassium and magnesium in the whole five years period (in P –4.9 kg, in K –27.8 kg and in Mg –2.8 kg as the mean value). The balance of calcium is not absolute, because it does not include the items of so-called maintenance liming, which have a great influence on the balance.

Compared with the previous period (1991–1995), the quantity of nutrients supplied in organic fertilizers decreased (at about 22%), as a consequence of the decreased numbers of farm animals, mainly of livestock. The portion of leguminous crops decreased as well as the yields of these crops and therefore the quantity of symbiotic nitrogen went down. It was less than 9.6% in the compared period. It is evident that the level of assets is substantially influenced by the consumption of nutrients in mineral fertilizers. Regarding nitrogen, it was in average 55.9 kg, which by was by 6.6 kg N/ha/year more compared with the period 1991–1995, but the consumption of potassium and phosphorus fertilizers went down in comparison with the previous cycle (in P to 4.8 and in K to 6.2 kg). It caused the decrease in phosphorus by 9.4% and by 10.4% in potassium. Compared with the previous period, the nutrient consumption decreased by harvests because the samplings of by-products were quantified in a different way. We took into consideration the fact that the above-ground green mass of root crops is usually not harvested and the straw of leguminous grain crops is not harvested for the reason of desiccation. The straw of oilseed crops and maize grown for grain is also not harvested and about 40% of the cereals straw is not exploited (it is mainly ploughed in). Taking into consideration the described realities and reached yields in the individual years, the consumption of nitrogen decreased by 15.1%, 18.2% in phosphorus, 29.1% in potassium and 30.1% in magnesium. We should mention that the consumption of mineral fertilisers is only for orientation, in connection with the final balance in magnesium and calcium, because at their quantification, we considered only the consumption of calcium fertilisers in wares (calcium substrates), but no assortment structure and species representation of the individual used fertilisers was at disposal for a precise calculation.

The structure of the grown crops and yields substantially changed in 1996–2000 compared to the previous five

years period. The acreage of winter rapeseed increased by 98.7%, perennial grasslands increased by 33%, but leguminous crops went down by 49.2%, potatoes by 20.1%, sugar beet by 23.1%, maize grown for green mass or ensilage by 14.9% and perennial fodder crops by 12.3%. In comparison with the previous period, the yields of many crops decreased (cereals by 2.9%, leguminous crops by 4.0%, perennial fodder crops by 14.1%, meadows by 8.7% and pastures by 21.8%). On the other hand, the yields of sugar beet evidently increased (12.7%), and also that of potatoes (20.8%).

Negative phosphorus, potassium, magnesium and calcium balances appeared therefore in the categories of soil reserves as in the mean agrochemical soil properties in the CR. The periods 1990–1992/1993–1998 were compared. Due to the negative economic balance, the share of soils with very low or low reserves of the available nutrients in the total arable land increased and with the exception of phosphorus, also on the soils of perennial grasslands. The share of the soils with unsuitable values of soil reaction (pH/KCl) is growing up. Comparing both cycles of the agrochemical arable soil testing, the pH value went down by 0.1 units as a mean value. The phosphorus reserve decreased by 4 mg/kg, potassium by 26 mg and magnesium by 1 mg.

The situation is different among districts, enterprises within district areas (even if they farm in comparable soil and climatic conditions) but even on individual fields in enterprises. Due to the unfavourable financial possibilities in the individual enterprises, the reproduction processes are insufficiently invested in. This is the main reason, as it was observed earlier, for the growth of the number of enterprises with a low level of gross and market production and due to the limited intensification inputs, the productive ability of soils is going down. The enterprises investing at the present time only in the crop products which are directed for the market are not exceptional.

REFERENCES

Albert E., Lippold H. (1997): NPK-Bilanzen in langjährigen Dauerversuchen mit Differenzierter mineralisch-organischer Düngung. 109. VDLUFA-Kongress, Germany, s. 85.

Bach M., Frede H.-G. (1997): Stickstoff-, Phosphor- und Kalium-Bilanzen für die Bundesrepublik Deutschland – Methodik, Trends und Bewertung von PARCOM-gemässen und flächenbezogenen Bilanzierungen. 109. VDLUFA-Kongress, Germany, s. 87.

Gorbanov S.P., Gorbanova A.S. (1998): Phosphorus fertilization management and balance of phosphorus in Bulgarian agriculture. 11th Inter. Symp. Codes of Good Fertilizer Practice and Balanced Fertilization, Pulawy, Poland: 467–474.

Götz B., Zethner G. (1997): Regionale Stoffbilanzen in der Landwirtschaft am Beispiel des Einzugsgebietes der Strem. 109. VDLUFA-Kongress, Lipsko, Germany, s. 108.

Hösch J., Dersch G., Köchl A. (1997): Nährstoffbilanz im Verlauf einer Fruchtfolge mit organischer und mineralischer Düngung. In: 109. VDLUFA-Kongress, Germany, s. 93.

Klír J. (1999): Bilance rostlinných živin. Stud. Inf. ÚZPI Praha (Rostlinná výroba), (7), 43 s.

Klír J., Kubát J., Pova D. (1995): Stickstoffbilanzen der Dauerfeldversuche in Prag. Mitteilgn. Dtsc. Bodenkundl. Gesellsch., 76: 831–834.

Kontrola úrodnosti půdy 1993–1998 (2000). ÚKZÚZ Brno, 10 s.

Statistická ročenka ČR (1998, 2000) (Yearbooks of the Czech Statistical Office). ČSÚ Praha.

Statistická ročenka ČR (2000). ČSÚ Praha.

Švec J. (1996, 1997, 1998, 1999, 2000): Definitivní údaje o sklizni zemědělských plodin v ČR. Statistické informace, ČSÚ.

Uebel E. (1998): Current fertilizers use Central/Eastern Europe (CEE) and the arising Consequences for soil fertility and crop production. Proc. 11th Inter. Symp. Codes of Good Fertilizer Practice and Balanced Fertilization. Pulawy, Polsko: 409–415.

Vostal J. (1997): Hospodářská bilance dusíku, fosforu, draslíku, hořčíku a vybraných položek vápníku v zemědělství České republiky od roku 1986. Zemědělská ekonomika, *43*, (12): 559–563.

Vostal J., Rosochatecká E. (2000): Hrubá rostlinná produkce v okresech ČR ve vztahu k úrovni hnojení a produkční schopnosti půd. Zemědělská ekonomika, *46* (8): 337–344.

Výsledky agrochemického zkoušení půd za období 1990–1992 (1993). SKZÚZ Brno, 99 s.

Wieser I., Hartl W. (1997): Stickstoffbilanzen verschiedener landwirtschaftlicher betreibe in Österreich. 109. VDLUFA-Kongress, Lipsko, Germany, s. 113.

Prof. Ing. Josef Vostal†, DrSc., Česká zemědělská univerzita v Praze, Česká republika