# Influence of different organic mineral fertilization on the yield structure and on changes of soil properties

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**ABSTRACT**

The monitoring was carried on in the years 1996–2000 in the international IOSDV (Internationale Ökologische Stickstoff Dauer Versuche) field trial running since 1983 in Lukavec, Pelhřimov district. In the given locality, there are low fertility sandy-loamy cambisoils, long-term average annual rainfall 653 mm, average annual temperature 7°C, altitude 620 m. In the field trials there were introduced different organic fertilizations and graduate N-doses. According to the complex diffusion analysis, statistically significant for the yields of winter wheat after potatoes was the impact of N fertilization, years, and double interactions, with the exception of different organic fertilization. The N doses up to 120 kg.ha$^{-1}$ after potatoes proved to be optimal from the viewpoint of winter wheat yields and quality. The situation was similar for winter barley. The results of diffusion analysis for individual years were analogical also in straw yields of both cereals. The highest N dose to potatoes (200 kg.ha$^{-1}$) resulted in the highest tuber yields, but the starch content was significantly lower. Graduated N doses increased in cereals the numbers of ears per m$^2$, but the mass of 1000 grains mostly decreased. In addition, N content in grain and straw increased with N doses, while pH annually decreased by 0.1 to 0.4. On plots without organic fertilization the N-balance was equilibrated with the annual application of 120 kg N.ha$^{-1}$ with straw embedding after cereals at 90 kg N.ha$^{-1}$ and on plots with stall dung to potatoes already at 70 kg N.ha$^{-1}$. On plots without N fertilization, the balance was passive also in P and K on plots without organic fertilization. A balance surplus was obtained already with the annual application of 15 kg P.ha$^{-1}$ and 83 kg K.ha$^{-1}$ and organic fertilization. With the annual fertilization with 22 kg P.ha$^{-1}$ and 83 kg K.ha$^{-1}$ and stall dung (30 t.ha$^{-1}$) once every three years the P and K content increased annually by 1 to 3 mg.kg$^{-1}$ of soil. Maximum levels of crop growing profitability were obtained with those doses of fertilizers with which also an equilibrated balance of nutrients was obtained.

**Keywords:** winter wheat; winter barley; potatoes; different organic fertilization; graduated N doses; structure and quality of yields; crop and soil analyses

Organic mineral fertilization takes a decisive share in both the level and quality of yields as well as in agrochemical indices and soil fertility, mostly in less fertile soils of regions which include the Czech Republic, country with predominant submontaneous agriculture. (Vrkoč et al. 1990, 1996, Vrkoč 1992, Skala and Vrkoč 1995, Vach and Vrkoč 1995 etc.). In less fertile brown cambisoils N fertilization is decisive (Vaněk et al. 1997a, b). An unsubstitutable part in these conditions is played by organic fertilization and the fertilizing impact of soil fertility reproducing plants (Vach and Vrkoč 1995).

In number of ours and other papers it was thus irrefutably proved that using of yield potential of low fertility brown cambisoils which prevail in the Czech Republic depends mainly on the intensity of organic fertilization and on N doses in mineral fertilizers. An important effect on the obtained crop yields also has a suitable forecrop and a productive variety as we have proved already earlier and quantified in the results of our different polyfactorial long-term field trials going on at several sites (Vrkoč 1992).

## MATERIAL AND METHODS

International IOSDV (Internationale Ökologische Stickstoff Dauer Versuche) field trials went on in the experimental station in Lukavec, Pelhřimov district, where less fertile sandy loamy cambisoils containing 2–3% of humus of lower quality prevail, with average annual rainfall of 653 mm, average annual temperature of 7°C and altitude of 620 m.

**International field trial (IOSDV)** – co-ordinated by J. Liebig University, Giessen, Germany, within the International Soil Science Society, included a three-year crop rotation (potatoes – winter wheat – winter barley), three ways of organic fertilization (A = without organic fertilization, B = stall dung 30 t.ha$^{-1}$ to potatoes, C = embedded straw 4 t.ha$^{-1}$ and white mustard as green manuring after the harvest of both cereals). Mineral fertilization included six levels: 0 – 0PK – $N_1$ – $N_2$ – $N_3$ – $N_4$ (40 – 80 – 120 – 160 kg N.ha$^{-1}$ to cereals, 50 – 100 – 150 – 200 kg N.ha$^{-1}$ to potatoes). The field trial was founded in 1983; this paper evaluates the results for the period 1996–2000.

Evaluation of yields, of their structure and quality, agrochemical analyses of crops and soil were done annually by standard methods.

## RESULTS AND DISCUSSION

The diffusion analysis of grain yields of **winter wheat** (Siria variety) in the years 1996–2000 in the international

Table 1. Yields of field crops (t/ha) from the international IOSDV trial according to organic fertilization, mineral fertilization, individual years and their incorporation into homogenous groups a–d* (Tukey $P$ = 95%)

| | | Winter wheat | | Winter barley | | Potatoes | |
|---|---|---|---|---|---|---|---|
| Average yield | | 5.2810 | * | 3.6386 | * | 42.7491 | * |
| Organic fertilization | A | 4.9060 | a | 3.3346 | a | 39.0073 | a |
| | B | 5.5069 | a | 3.7160 | a | 44.8898 | b |
| | C | 5.4302 | a | 3.8653 | a | 44.3502 | b |
| Mineral fertilization | 0 | 3.3713 | a | 2.1533 | a | 33.5309 | a |
| | PK | 3.3218 | a | 2.3462 | a | 33.8802 | a |
| | $N_1$ | 4.5591 | b | 3.1564 | b | 42.5131 | b |
| | $N_2$ | 6.1722 | c | 4.3018 | c | 46.3780 | bc |
| | $N_3$ | 6.9758 | d | 4.8567 | cd | 49.6049 | c |
| | $N_4$ | 7.2860 | d | 5.0173 | d | 50.5876 | c |
| Year | 1996 | 4.8820 | ab | 3.3743 | b | 35.4467 | a |
| | 1997 | 4.1011 | a | 2.2198 | a | 35.6085 | a |
| | 1998 | 6.8535 | c | 4.5943 | c | 52.9546 | c |
| | 1999 | 5.3000 | b | 4.4744 | c | 43.2635 | b |
| | 2000 | 5.2685 | b | 3.5304 | b | 46.4722 | b |

* if there is the same letter attached to the yields, the mutual values are not statistically significant, different letters indicate a statistically significant difference at the level of significance 95%

IOSDV field trial showed (Tables 1 and 2) that the total impact of N fertilization, years, and double interactions was, in accordance with our previous finding (Vrkoč et al. 1990), statistically significant in the average of years. N fertilization manifested the most evidently, while different organic fertilization did not significantly differ in its subsequent impact on winter wheat. No significant difference was found between the 0 and 0PK variants, as well as between $N_3$ and $N_4$ (120 and 160 kg N.ha$^{-1}$). In accordance with Vaněk et al. (1997a, b) and Šroller and Šimon (2000), we can consider the N dose up to 120 kg N.ha$^{-1}$ after the stall-dung manured potatoes (when also the best qualitative parameters were obtained) as optimal in the given low fertile brown soils. The stall dung effect was equiva-

Table 2. Yields of field crops (t.ha$^{-1}$) from the international IOSDV trial in the interaction of organic and mineral fertilization and reliability interval (Tukey $P$ = 95%)

| Interaction | Winter wheat | | | Winter barley | | | Potatoes | | |
|---|---|---|---|---|---|---|---|---|---|
| | average | reliability interval | | average | reliability interval | | average | reliability interval | |
| | | < 95% | > 95% | | < 95% | > 95% | | < 95% | > 95% |
| A × 0 | 2.9980 | 2.4849 | 3.5111 | 1.7773 | 1.4521 | 2.1026 | 29.4160 | 25.9370 | 32.8950 |
| A × PK | 2.7673 | 2.3495 | 3.1852 | 1.8867 | 1.5304 | 2.2429 | 28.4460 | 24.4850 | 32.4070 |
| A × $N_1$PK | 4.0440 | 3.4831 | 4.6049 | 2.9353 | 2.3619 | 3.5088 | 38.0613 | 32.2850 | 43.8377 |
| A × $N_2$PK | 5.7860 | 5.1701 | 6.4019 | 3.9607 | 3.2814 | 4.6399 | 42.8553 | 37.7255 | 47.9852 |
| A × $N_3$PK | 6.7027 | 6.1548 | 7.2506 | 4.5467 | 4.0204 | 5.0729 | 46.6933 | 43.0214 | 50.3653 |
| A × $N_4$PK | 7.1380 | 6.6782 | 7.5978 | 4.9007 | 4.4087 | 5.3926 | 48.5720 | 44.5333 | 52.6107 |
| B × 0 | 3.5820 | 3.0858 | 4.0782 | 2.2373 | 1.8172 | 2.6574 | 35.7580 | 32.5091 | 39.0069 |
| B × PK | 3.5367 | 2.9664 | 4.1069 | 2.4953 | 2.0682 | 2.9224 | 36.6887 | 32.3154 | 41.0619 |
| B × $N_1$PK | 4.8193 | 4.1596 | 5.4791 | 3.2200 | 2.7050 | 3.7350 | 44.8493 | 40.1168 | 49.5818 |
| B × $N_2$PK | 6.4067 | 5.7250 | 7.0884 | 4.4173 | 3.7150 | 5.1197 | 48.7520 | 44.8294 | 52.6746 |
| B × $N_3$PK | 7.2387 | 6.6908 | 7.7866 | 4.9233 | 4.2631 | 5.5835 | 51.9773 | 47.9208 | 56.0339 |
| B × $N_4$PK | 7.4580 | 6.9099 | 8.0061 | 5.0027 | 4.4460 | 5.5593 | 51.3133 | 46.6427 | 55.9839 |
| C × 0 | 3.5340 | 3.0902 | 3.9778 | 2.4453 | 2.0007 | 2.8899 | 35.4187 | 32.0521 | 38.7853 |
| C × PK | 3.6613 | 3.0848 | 4.2379 | 2.6567 | 2.2365 | 3.0768 | 36.5060 | 32.1654 | 40.8466 |
| C × $N_1$PK | 4.8140 | 4.2293 | 5.3987 | 3.3140 | 2.7554 | 3.8726 | 44.6287 | 39.8383 | 49.4190 |
| C × $N_2$PK | 6.3240 | 5.6651 | 6.9829 | 4.5273 | 3.6662 | 5.3884 | 47.5267 | 43.1269 | 51.9265 |
| C × $N_3$PK | 6.9860 | 6.3823 | 7.5897 | 5.1000 | 4.4532 | 5.7468 | 50.1440 | 46.3302 | 53.9578 |
| C × $N_4$PK | 7.2620 | 6.7589 | 7.7651 | 5.1487 | 4.6087 | 5.6886 | 51.8773 | 47.3518 | 56.4029 |

Table 3. Effects of organic fertilization on the number of ears and the mass of 1000 grains in winter wheat and winter barely in Lukavec – IOSDV (average of monitored years)

| Organic fertilization | Degree of N-fertilization | Number of ears per 1 $m^2$ | | Mass of 1000 grains (g) | |
|---|---|---|---|---|---|
| | | winter wheat | winter barley | winter wheat | winter barley |
| Without organic fertilization (A) | 0 | 373 | 330 | 41.23 | 38.53 |
| | PK | 376 | 358 | 41.78 | 38.38 |
| | $N_1PK$ | 417 | 382 | 44.70 | 39.57 |
| | $N_2PK$ | 466 | 456 | 45.49 | 40.96 |
| | $N_3PK$ | 494 | 451 | 45.96 | 40.99 |
| | $N_4PK$ | 521 | 460 | 46.06 | 41.18 |
| Stall dung to potatoes (B) | 0 | 404 | 345 | 43.52 | 38.28 |
| | PK | 397 | 358 | 43.85 | 39.55 |
| | $N_1PK$ | 418 | 399 | 45.87 | 39.99 |
| | $N_2PK$ | 475 | 431 | 46.35 | 41.03 |
| | $N_3PK$ | 499 | 472 | 46.16 | 41.20 |
| | $N_4PK$ | 535 | 467 | 46.76 | 41.64 |
| Straw embedding after cereal + forecrop (C) | 0 | 401 | 370 | 42.98 | 38.31 |
| | PK | 404 | 373 | 43.91 | 39.53 |
| | $N_1PK$ | 428 | 421 | 45.39 | 40.15 |
| | $N_2PK$ | 462 | 435 | 45.82 | 41.09 |
| | $N_3PK$ | 503 | 482 | 45.71 | 40.78 |
| | $N_4PK$ | 513 | 474 | 46.16 | 40.88 |

lent to about 40 kg $N.ha^{-1}$. The subsequent impact of stall dung to potatoes as forecrop increased the yields of the following winter wheat of about 0.6 $t.ha^{-1}$. The results of the diffusion analysis for individual years were altogether analogical.

On the contrary, in the grain yields of **winter barley** (Okal variety) in the IOSDV field trial the impact of all the monitored factors (subsequent impact of different organic fertilization, N fertilization and years), as well as mutual double interactions, was statistically significant (Tables 1 and 2). The lowest yields were naturally on plots without organic fertilization, the highest ones with $N_4$ (160 kg $N.ha^{-1}$). Similar results were obtained also in individual years; the same situation was in straw yields.

Table 4. Results of agrochemical analyses of soil from the international IOSDV trial – Lukavec year 2000

| | Variant | pH/KCl | Basic nutrients content in $mg.kg^{-1}$ soil | | | | $C_{ox}$ (%) | $N_t$ (%) |
|---|---|---|---|---|---|---|---|---|
| | | | P | K | Ca | Mg | | |
| Winter wheat | $A\ N_1$ | 5.62 | 139.8 | 270 | 922 | 81.3 | 1.787 | 0.160 |
| | $A\ N_3$ | 4.94 | 123.5 | 231 | 794 | 65.0 | 1.854 | 0.140 |
| | $B\ N_1$ | 5.76 | 156.9 | 495 | 966 | 90.8 | 2.047 | 0.175 |
| | $B\ N_3$ | 4.92 | 145.9 | 338 | 836 | 67.8 | 2.113 | 0.182 |
| | $C\ N_1$ | 5.57 | 114.0 | 264 | 922 | 72.9 | 1.834 | 0.162 |
| | $C\ N_3$ | 4.68 | 139.3 | 137 | 753 | 57.1 | 2.112 | 0.167 |
| Winter barley | $A\ N_1$ | 5.82 | 100.7 | 186 | 922 | 132.4 | 2.470 | 0.148 |
| | $A\ N_3$ | 5.45 | 104.6 | 180 | 879 | 118.6 | 1.852 | 0.146 |
| | $B\ N_1$ | 5.65 | 121.9 | 270 | 836 | 130.8 | 2.024 | 0.158 |
| | $B\ N_3$ | 5.17 | 146.6 | 304 | 836 | 115.5 | 2.275 | 0.175 |
| | $C\ N_1$ | 5.31 | 107.6 | 180 | 879 | 111.3 | 2.006 | 0.144 |
| | $C\ N_3$ | 4.87 | 131.2 | 167 | 794 | 97.9 | 2.011 | 0.148 |
| Potatoes | $A\ N_1$ | 5.59 | 126.0 | 186 | 966 | 107.6 | 1.672 | 0.146 |
| | $A\ N_3$ | 4.59 | 140.8 | 192 | 794 | 95.9 | 1.869 | 0.166 |
| | $B\ N_1$ | 6.22 | 177.6 | 387 | 1101 | 134.3 | 1.882 | 0.184 |
| | $B\ N_3$ | 5.63 | 181.5 | 297 | 922 | 142.2 | 1.936 | 0.198 |
| | $C\ N_1$ | 5.80 | 132.7 | 257 | 1011 | 115.4 | 1.718 | 0.158 |
| | $C\ N_3$ | 5.47 | 138.3 | 237 | 879 | 132.2 | 1.966 | 0.173 |

Similarly, as for winter wheat, also for **potatoes** (Karin variety) the general statistical evaluation showed that the variability of yields due to different organic fertilization, different N doses, years, and all double interactions was statistically significant (Tables 1 and 2). Statistically significant differences were obtained only between the 0 and 0PK variants when compared with $N_1$ and $N_2$ and between $N_1$ and $N_4$. This highest nitrogen dose ($N_4$ = 200 kg N.ha$^{-1}$) lead however to the highest tuber yield, but the starch content significantly decreased. When using the dose of 30 t.ha$^{-1}$ of stall dung, the optimal was in the average of years the dose only up to do 80–100 kg N.ha$^{-1}$. The results of diffusion analysis for individual years were altogether analogical.

Increased N doses and organic fertilization increased, similarly as in our former field trials (Vach and Vrkoč 1995), the number of ears/m$^2$ in winter wheat and in winter barley. However, in some years, the highest N doses reduced the mass of 1000 grains (Table 3).

The highest percentage of N content in grain and straw of cereals as well as in potato tubers was always found in plots with highest N doses, for other nutrients the values somehow oscillated.

Graduated N doses resulted, in accordance with Vaněk et al. (1997a, b), in a soil acidification by 0.1 to 0.4 pH value, which was naturally manifested by a decrease of Ca and Mg content in soil (Table 4). A similar tendency was observed also in P and K content in soil. On the contrary, increased N doses increased after five years the content of total nitrogen, $C_{ox}$ and humus. In general, a narrow connection was found between the level of obtained yields and the N content in soil (Skala and Vrkoč 1995, Vaněk et al. 1997a, b).

The analysis of nutrient balance in the field IOSDV trial showed (Hazucha et al. 1999) that in plots without organic fertilization there was an equilibrated N balance with the annual application of about 120 kg N.ha$^{-1}$, with straw embedding after cereals with about 90 kg N.ha$^{-1}$ and in plots with stall dung to potatoes with about 70 kg N.ha$^{-1}$. In plots without N fertilization, the balance was passive also in P and K on plots without organic fertilization. With annual application of 15 kg P.ha$^{-1}$, 83 kg K.ha$^{-1}$ and organic fertilization, a balance surplus was already obtained. In total, with application of 22 kg P.ha$^{-1}$ and 83 kg K.ha$^{-1}$ in combination with stall dung once every three years, the P and K content increased every year by 1–3 mg.kg$^{-1}$ of soil.

The economic analysis showed that maximal profitability level in crop production was obtained with those doses of mineral fertilization with which also an equilibrated balance of nutrients was obtained.

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## ABSTRAKT

**Vliv různého organicko-minerálního hnojení na strukturu výnosu a změny půdních vlastností**

Výzkum proběhl v letech 1996 až 2000 na základě mezinárodního polního pokusu IOSDV, založeného v roce 1983 v Lukavci, okres Pelhřimov. Na dané lokalitě jsou málo úrodné písčitohlinité kambizemě, dlouhodobý roční úhrn srážek činí 653 mm, průměrná roční teplota 7°C, nadmořská výška 620 m. V polním pokusu byly zařazeny: různé organické hnojení a stupňované dávky N. U výnosů ozimé pšenice po bramborách byl podle souborné analýzy rozptylu vliv hnojení N, ročníků i dvojitých interakcí statisticky významný, s výjimkou různého organického hnojení. Jako optimální se po bramborách ukázala s ohledem na výnosy i kvalitu ozimé pšenice dávka do 120 kg N.ha$^{-1}$. U ozimého ječmene tomu bylo podobně. Výsledky analýzy rozptylu za jednotlivé roky i u výnosů slámy byly u obou obilnin analogické. Nejvyšší dávka N k bramborům (200 kg.ha$^{-1}$) vedla sice k nejvyššímu výnosu hlíz, ale při silném poklesu škrobnatosti. Stupňované dávky N

zvyšovaly u obilnin počet klasů na $m^2$, avšak hmotnost 1000 zrn se většinou snižovala. Rovněž obsah N v zrnu i ve slámě se s dávkami N zvyšoval, pH půdy se ročně snižovalo o 0,1–0,4. Na dílcích bez organického hnojení byla vyrovnaná bilance N při každoroční aplikaci 120 kg $N.ha^{-1}$, se zaorávkami slámy po obilninách při 90 kg $N.ha^{-1}$ a na dílcích s chlévským hnojem k bramborům již při 70 kg $N.ha^{-1}$. Na dílcích bez N hnojení byla bilance pasivní i u P a K na dílcích bez organického hnojení. Při každoroční aplikaci 15 kg $P.ha^{-1}$ a 83 kg $K.ha^{-1}$ a organického hnojení byl již dosažen bilanční přebytek. Celkově při každoročním hnojení 22 kg $P.ha^{-1}$ a 83 kg $K.ha^{-1}$ a chlévským hnojem (30 $t.ha^{-1}$) jednou za tři roky se obsah P a K zvyšoval ročně o 1–3 $mg.kg^{-1}$ půdy. Maximálních hodnot rentability pěstování plodin bylo dosaženo při těch dávkách hnojiv, při kterých bylo dosaženo i vyrovnané bilance živin.

**Klíčová slova:** ozimá pšenice; ozimý ječmen; brambory; různé organické hnojení; stupňované dávky N; struktura a kvalita výnosů; analýzy rostlin a půdy

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