# Effect of different straw management practices on yields of continuous spring barley

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**ABSTRACT**

Field experiments were conducted in the maize-growing region on heavy gleic fluvisol from 1974 to 2000. Three variants of straw management (straw harvested, incorporated into soil and burned), two variants of soil tillage (conventional plough tillage to 0.22 m, shallow disc tillage to 0.12–0.15 m) and three variants of fertilization (30, 60 and 90 kg N.ha$^{-1}$) were studied. After conventional tillage, the highest yield was obtained in the variant with burned straw (5.50 t.ha$^{-1}$), followed by the variant with straw incorporated into soil (5.40 t.ha$^{-1}$) and the lowest after harvested straw (5.01 t.ha$^{-1}$). At shallow tillage, lower yields were assessed in all variants of straw management in comparison with conventional tillage (after straw burning 5.07 t.ha$^{-1}$, incorporation into soil 4.66 t.ha$^{-1}$ and harvest 4.54 t.ha$^{-1}$). The ranking of variants was identical to that in inversion tillage; however, the yield increased more after straw burning in comparison with its incorporation into soil. Yields increased regularly along with increasing rates of nitrogen. If long-term effects of straw incorporation on yields and yield trends were evaluated (in comparison with straw harvest), statistically significant decrease in yields was assessed after shallow in contrast with increase in yields after deeper straw incorporation.

**Keywords:** spring barley; grain yield; straw management; soil tillage; mineral fertilization

Changes in economic conditions are accompanied by changes in the structure of crop and livestock production. A number of agricultural enterprises without livestock production, or with livestock production but without need of straw, have been increasing. At the same time, the structure of crops has been narrowing and concentration of cereals has been rising. A question arises how to use straw, which is not necessary for livestock production. A lack of farmyard manure and necessity of maintaining soil fertility with supply of organic matter leads to direct straw fertilization.

There are now problems of appropriate techniques for straw fertilization in both conventional and particularly minimum soil tillage practices that have been more widely used.

Effects of various straw management practices on yields of successive crops and modifications of the soil environment have been described by a number of authors (Harper 1989, Koch and Baeumer 1989, Krogmeier and Bremner 1989, Ball and Robertson 1990, Rule 1990, Christian and Bacon 1991, Thompson 1992, Johnson and Smith 1993). The studies show that straw fertilization, and particularly in combination with minimum soil tillage (shallow incorporation of straw into soil, direct sowing in no-tilled soil or surface-tilled soil) often results in difficult establishment of stands. A higher amount of straw in the upper layer or on the surface of soil (especially in the case of its non-uniform distribution across the field) does not allow deposit seeds uniformly and at the required depth. Furthermore, straw can induce inhibitory effects on germination, emergence and initial growth of following crops. The inhibition mostly combines physical and biochemical effects (water consumption for straw decomposition, phytotoxic substances released from straw or produced by its decomposition).

The objective of the presented study is to evaluate long-term effects of different straw management practices in combination with different soil tillage techniques and mineral fertilization on yields of continuous spring barley under dry and warm conditions of the maize-growing region.

## MATERIAL AND METHODS

Different straw management practices in combination with conventional and minimum soil tillage and different mineral fertilization were evaluated in a stationary field experiment from 1974 to 2000. The experiment was established in split-plot design in four replicates. The area of the plot was 37.1 m$^2$ (5.3 m × 7 m).

### Characteristics of the experiment site

The altitude is 176 m above sea level, average annual temperature 9.54°C, average rainfall 480 mm (30 years average, 1971–2000).

Soil characteristics: heavy gleic fluvisol ($FM_G$), neutral pH, humus content in topsoil 2.5% and content of available phosphor and potassium good.

Table 1. Yields of continuous spring barley ($t.ha^{-1}$), average of 1974–2000

| Soil tillage | Nitrogen fertilization | Straw management | | | Average |
|---|---|---|---|---|---|
| | | straw harvested | straw incorporated | straw burned | |
| Conventional plough | 30 | 4.85 | 5.29 | 5.39 | 5.17 |
| tillage to 0.22 m | 60 | 4.98 | 5.42 | 5.48 | 5.29 |
| | 90 | 5.19 | 5.49 | 5.64 | 5.44 |
| | average | 5.01 | 5.40 | 5.50 | 5.30 |
| Shallow tillage to 0.12–0.15 m | 30 | 4.19 | 4.25 | 4.64 | 4.36 |
| | 60 | 4.59 | 4.73 | 5.11 | 4.81 |
| | 90 | 4.84 | 4.99 | 5.46 | 5.10 |
| | average | 4.54 | 4.66 | 5.07 | 4.76 |
| Average | | 4.78 | 5.03 | 5.29 | 5.03 |

**Variants**

Variants of straw management:

1. Straw harvested (removed)
2. Straw incorporated into soil
3. Straw burned

Variants of soil tillage:

1. Conventional tillage (ploughing) to a depth of 0.22 m
2. Soil tillage with a disc cultivator to a depth of 0.12–0.15 m

Variants of mineral fertilization (in kg of pure nutrients.$ha^{-1}$):

1. 30 N, 26 P, 66 K
2. 60 N, 40 P, 100 K
3. 90 N, 40 P, 100 K

Phytopathogenic agents were controlled uniformly in all variants of the experiment according to the methods of the State Phytosanitary Administration.

**RESULTS**

Effects of different straw management practices on yields of continuous spring barley differed in dependence on soil tillage practices and mineral fertilization (Table 1).

After inversion tillage to the depth of 0.22 m, the highest yield of spring barley on average for 1974–2000 was produced in the variant with burned straw (5.50 $t.ha^{-1}$) and slightly lower yield was obtained in the variant with straw incorporated into soil (5.40 $t.ha^{-1}$). Considerably lower yields were assessed in the variant with harvested straw (5.01 $t.ha^{-1}$). The ranking of yields mentioned above was assessed in all variants of mineral fertilization with increasing nitrogen rates (30, 60, 90 $kg.ha^{-1}$).

The identical ranking of yields was recorded at shallow soil tillage with a disc cultivator to the depth of 0.12–0.15 m (the highest yield was in the variant with burned straw 5.07 $t.ha^{-1}$, followed by straw incorporated into soil 4.66 $t.ha^{-1}$ and the lowest yield at harvested straw 4.54 $t.ha^{-1}$) again in all levels of mineral fertilization. However, there is a bigger difference between the variants with burned and incorporated straw.

On average of all variants of straw management, the highest yields of spring barley were obtained after inversion tillage (after inversion tillage 5.50 $t.ha^{-1}$, after shallow tillage 5.50 $t.ha^{-1}$). The largest difference in favour of

Table 2. Statistical assessment of yield trends

| Soil tillage | Straw management | Fertilization | Parameters of fitted line | | Significance of *b* parameter | |
|---|---|---|---|---|---|---|
| | | | *a* | *b* | *p* | |
| Conventional plough | straw incorporated | 30 | 1.035 | 0.004 | 0.225 | |
| tillage to 0.22 m | | 60 | 1.008 | 0.006 | 0.390 | * |
| | | 90 | 0.997 | 0.004 | 0.072 | |
| | straw burned | 30 | 0.974 | 0.010 | 0.035 | * |
| | | 60 | 0.993 | 0.008 | 0.036 | * |
| | | 90 | 0.980 | 0.008 | 0.042 | * |
| Shallow tillage | straw incorporated | 30 | 1.090 | –0.005 | 0.043 | * |
| | | 60 | 1.122 | –0.007 | 0.002 | * |
| | | 90 | 1.044 | –0.001 | 0.657 | |
| | straw burned | 30 | 1.146 | –0.003 | 0.724 | |
| | | 60 | 1.103 | 0.001 | 0.924 | |
| | | 90 | 1.075 | 0.004 | 0.527 | |

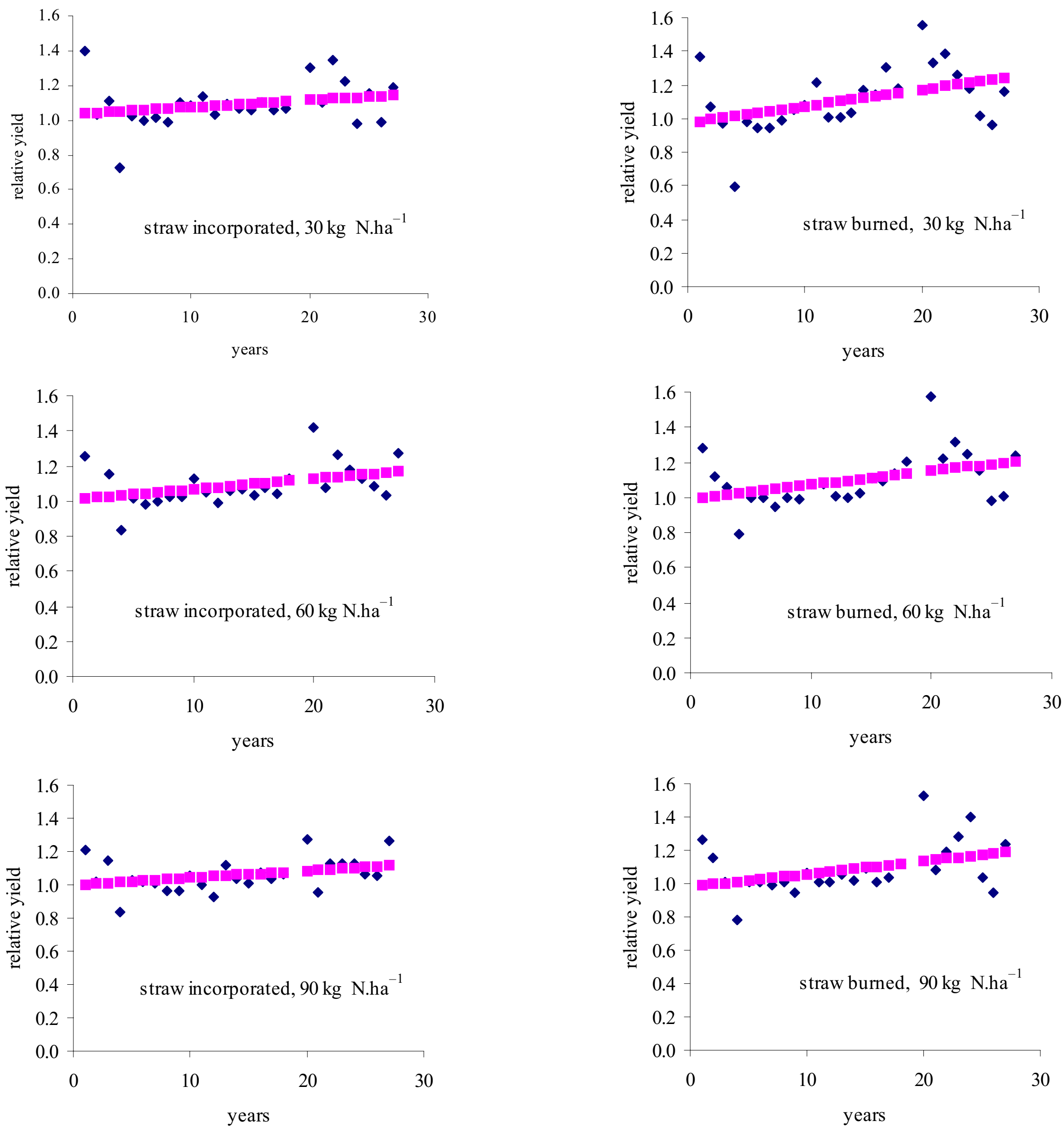


Figure 1. Relative yields of continuous spring barley at conventional soil tillage (conventional tillage to 0.22 m), Žabčice 1974–2000

deeper soil tillage was found in the variant with straw incorporated into soil (0.74 t.ha$^{-1}$). The differences were markedly smaller in variants with harvested and burned straw (0.47 and 0.43 t.ha$^{-1}$).

Higher variation in yields in individual years was determined at shallow soil tillage (coefficient of variation for shallow tillage 20.85%, for conventional tillage 13.69%).

In all variants of straw management and soil tillage, yields of spring barley increased along with increasing nitrogen rates, more markedly in variants with shallow soil tillage. In addition to this, effects of long-term straw incorporated and burned vs. harvested straw on yields and yield trends of spring barley were evaluated. Figures 1 and 2 show relative yields and long-term yield trends in variants with straw incorporation and straw burning (ratio between yields in these variants and the yield obtained in the variant with harvested straw) and Table 2 gives statistical evaluation.

At deeper soil tillage to 0.22 m, yields increased with time in the variant with incorporated straw (in relation to harvested straw) and favourable effects increased along with long-term use of this practice. The yields significantly increased at nitrogen rates of 60 and 90 kg.ha$^{-1}$. As illustrated in figures, straw burning increased yields of spring barley more than straw incorporated into soil. The effect of long-term straw burning on yield increase with time is significant at nitrogen rates of 30 and 60 kg.ha$^{-1}$.

At shallow soil tillage to 0.12–0.15 m, by contrast, the decrease in yields was recorded in the variant with straw incorporated into soil over time. The yields decreased significantly at low and medium nitrogen rates (30 and

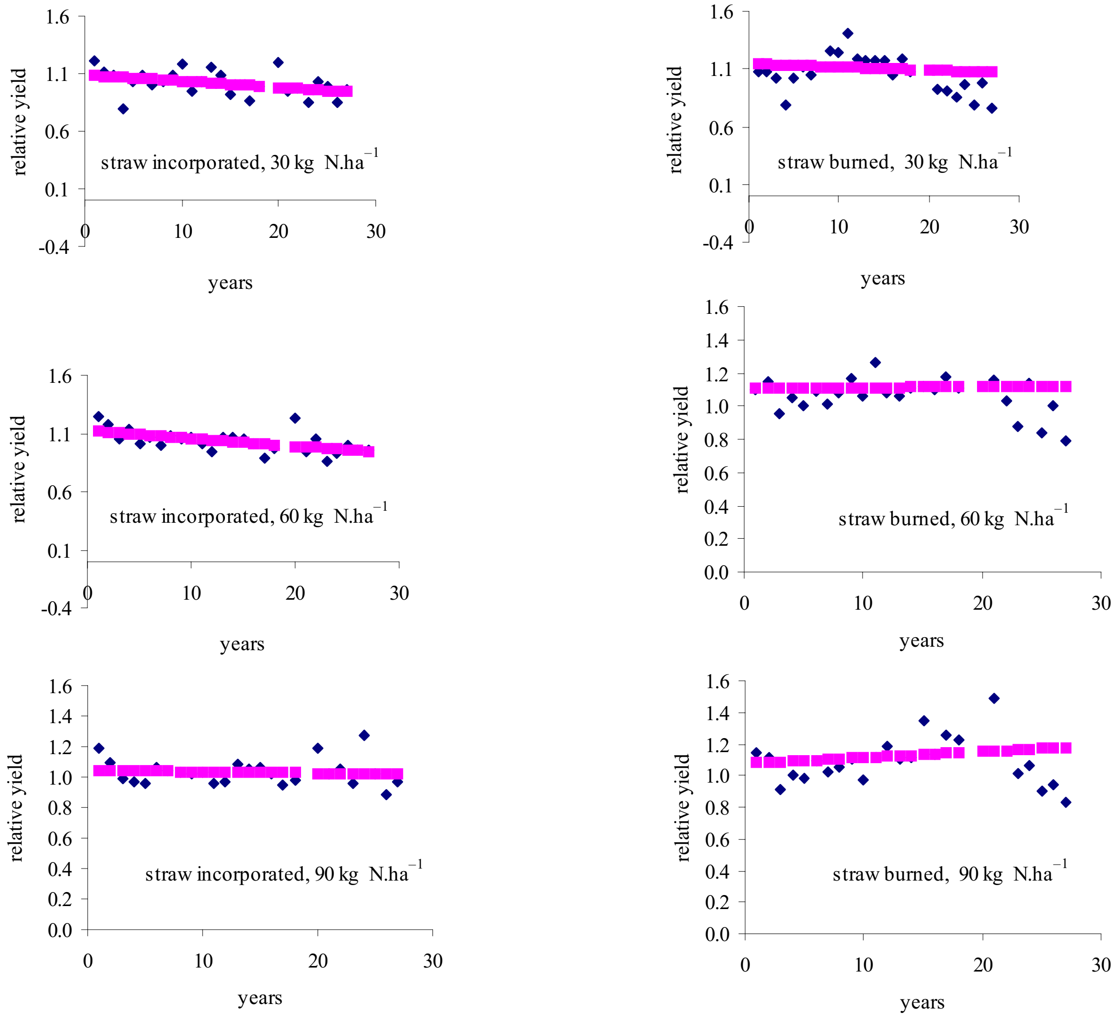


Figure 2. Relative yields of continuous spring barley at shallow soil tillage (0.12–0.15 m), Žabčice 1974–2000

60 kg.ha$^{-1}$). A higher nitrogen rate (90 kg.ha$^{-1}$) compensated for, to a certain level, adverse effects of shallow straw incorporation on yields of spring barley.

The variant with straw burning combined with shallow soil tillage tended to decreasing yields at a low nitrogen rate of 30 kg.ha$^{-1}$ only. A medium nitrogen rate did not change markedly the yields and a higher nitrogen rate shows an apparent trend toward yield increase. Changes in yield trends at all nitrogen rates were statistically insignificant.

## DISCUSSION

Straw fertilization under minimum soil tillage practices can induce, particularly under drier agroecological conditions, inhibitory effects on germination, growth and yields of successive crops.

Investigations into inhibitory effects of organic substances revealed that straw of spring barley demonstrated the highest inhibitory effects (Řídký 1977). Higher inhibitory effects in comparison with straw of the other cereals are also reported by Kim et al. (1987), Kati and Froud-Williams (1999), Ben-Hammouda and Oueslati (1999), and others.

Data on long-term effects of straw incorporation and burning in comparison with straw harvested on yields and yield trends of spring barley show a trend toward yield decrease with time after shallow incorporation of straw into soil as well as some possibilities of compensating for this adverse effect with nitrogen fertilization. By contrast, yields increased with time at deeper soil tillage (to 0.22 m) and this favourable effect grew along with long-term application. Relative yields increased with time more markedly if straw was burned than incorporated at deeper soil tillage. Straw burning in combination with shallow soil tillage decreased relative yields with time at a low nitrogen rate (30 kg.ha$^{-1}$) and increased them at medium (60 kg.ha$^{-1}$) and particularly at a higher nitrogen rate (90 kg.ha$^{-1}$). In general, results demonstrate favourable effects of straw burning in continuous spring barley. This fact can be related to reduction of inhibitory effects of straw and post-harvest residues and phytosanitary effects of straw burning. Feasibility of this treatment is, however, limited in practice with regard to technical problems and adverse environmental impacts.

Strongly positive effects of straw burning vs. straw incorporation into soil on yields of continuous spring barley on luvi-haplic chernozem in the beet-growing region were also observed by Hrubý et al. (1996).

Soon (1999) gives long-term data on effects of different straw management practices (straw harvested, straw incorporated in soil by inversion tillage and disc tillage) on yields of spring barley in continuous cropping. In contrast with our results, under colder and more humid conditions, yields tended to decrease after deeper straw incorporation by inversion tillage.

Rule (1990) evaluated different straw management practices (straw incorporated into soil by inversion and disc tillage, straw burning) under various soil conditions on experimental farms across Great Britain. Based on results, he indicates that conventional tillage is satisfactory on light and medium soils. On heavy soils, however, it can even reduce yields.

Results of studying the effects of different straw management practices on yields of successive crops depend, to a certain level, on conditions of experiments. Adverse effects of higher concentration of straw in the upper layer of soil at minimum soil tillage are more apparent under drier agroecological conditions.

Our data obtained in a long-term field experiment on heavy gleic fluvisol under dry and warm conditions of the maize-growing region generally demonstrate that shallow soil tillage in continuous spring barley for a long time, and particularly at incorporation of straw into soil, leads to gradual decrease in both a level and stability of yields.

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**ABSTRAKT**

**Vliv různých způsobů hospodaření se slámou na výnosy jarního ječmene pěstovaného v monokultuře**

Pokusy probíhaly v kukuřičné výrobní oblasti na těžké fluvizemi glejové v letech 1974 až 2000. Byly v nich zařazeny tři varianty hospodaření se slámou (sláma sklizená, zapravená do půdy a pálená), dvě varianty zpracování půdy (orba na 0,22 m a zpracování talířovým nářadím na 0,12–0,15 m) a tři varianty hnojení (30, 60 a 90 kg N.ha$^{-1}$). Při orbě byl nejvyšší výnos po pálení slámy (5,50 t.ha$^{-1}$), dále po zapravení do půdy (5,40 t.ha$^{-1}$) a nejnižší byl po sklizni slámy (5,01 t.ha$^{-1}$). Při mělkém zpracování byly ve srovnání s orbou u všech variant hospodaření se slámou dosaženy nižší výnosy (po pálení slámy 5,07, po zapravení do půdy 4,66 a po sklizni 4,54 t.ha$^{-1}$). Pořadí variant bylo stejné jako u orby, patrné je zde však výraznější zvýšení výnosů po pálení slámy ve srovnání s jejím zapravením do půdy. Se zvyšující se dávkou dusíku docházelo pravidelně ke zvyšování výnosů. Při hodnocení dlouhodobého vlivu zapravování slámy (v porovnání se sklizní slámy) na výnosy a výnosové trendy byl zaznamenán statisticky průkazný pokles výnosů po mělkém a naopak nárůst výnosů po hlubším zapravování slámy.

**Klíčová slova:** jarní ječmen; výnos zrna; hospodaření se slámou; zpracování půdy; minerální hnojení

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