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*Original Research*

# Direct and Secondary Effects of Soil Mulching with Straw on Fresh Mass and Number of Weeds, Vegetable Yield

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## Abstract

We investigated the effect of soil mulching with rye straw (*Secale cereale*) applied at a rate of 5 t·ha$^{-1}$ on a weed infestation in cabbage (*Brassica oleracea* L. var. *capitata* L. *f. rubra*) cultivated in the first year, and onion (*Allium cepa* L. var. *cepa* Helm.) grown in the second year after mulching. Straw mulch was applied during the final 10 days of July and plough-incorporated on three dates (in the autumn, the final 10 days of October; in the spring of the next year, the second 10 days of May; mulch non-incorporated until the time of cabbage harvest). The study was conduced at the experimental farm in Zawady located in centraleastern Poland, in 2002-06. The mulching effect of 5 t·ha$^{-1}$ rye straw was compared to conventional farmyard manure fertilization at a dose of 40 t·ha$^{-1}$, as well as a control without manure fertilization or mulching. The weed infestation of plots where straw mulch was left until the time of cabbage harvest was significantly smaller in comparison with the autumn- and spring-incorporation of straw. In the period of cabbage growth, the fresh mass and number of weeds in the plots with non-incorporated mulch were significantly lower than in the control without mulching and farmyard manure-fertilized plots. A significant mulch effect on weed infestation was found in the first year following mulch application. No significant secondary effect of straw mulch and date of ploughing down on weed infestation in onion was found. The cabbage and onion yield achieved after straw mulch was similar to the yield after farmyard manure applied at a dose of 40 t·ha$^{-1}$.

**Keywords:** farmyard manure, rye straw (*Secale cereale*), mulch, weed infestation, vegetable yield

## Introduction

In the integrated and ecological agriculture systems more attention is being paid to the longest possible period of soil coverage with plant mulches and mulches from straw left after cereal grain harvest [4, 12, 16, 20]. Simplifications in soil cultivation associated with an application of mulches may influence weed pressure. Such an impact has been reported in the studies by Błażewicz-Woźniak et al. [2] and Kęsika and Błażewicz-Woźniak [11]. A number of studies have documented that straw mulch is a good means of decreasing weed emergence and growth [3, 7, 8, 17, 19, 22]. There is a limited number of studies pertaining to an application of straw mulch in the cultivation of vegetables. Studies on the application of straw mulches in bean and onion cultivation were carried out by Jodaugienė et al. [10]. Radics and Bognár [18] examined mulches applied in green bean and tomato growing, whereas Grassbaugh et al. [8] and Döring [6] investigated the effect of mulches in tomato and potato cultivation, respectively.

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There is no information in literature about how straw mulch affects weed pressure depending on the date of mulch incorporation and secondary affect of straw mulching. What is also important from the point of view of agricultural practice is to compare weed infestation of the soil and vegetable yields following straw mulches and with farmyard manure application as well as no-mulch cultivation.

The present work measures direct and secondary effects of rye straw mulch and the date of mulch incorporation on the weed infestation and red cabbage and onion yield cultivated, in the first and second years after mulching.

## Material and Methods

A field experiment was carried out in 2002-06 at the experimental farm in Zawady. The soil was Luvisol; the soil organic matter (SOM) content averaged 1.5% and its humus horizon reached a depth of 30-40 cm. Before the experiment set-up, soil pH determined in $H_2O$ was 5.73. Total phosphorus content in soil was 67 mg·kg$^{-1}$ adm, potassium 108 mg·kg$^{-1}$ adm, magnesium 39 mg·kg$^{-1}$ adm, N-$NO_3$ 10 mg·kg$^{-1}$ adm, N-$NH_4$ 6 mg·kg$^{-1}$ adm, calcium 380 mg·kg$^{-1}$ adm. The study was established as a split-block design in three replications. Straw mulch was applied in the years 2002-04. The red cabbage cv 'Koda' (*Brassica oleracea* L. var. *capitata* L. *f. rubra*) was cultivated following mulch application in the years 2003-05, and the onion cv 'Kristine' (*Allium cepa* L. var. *cepa* Helm.) followed red cabbage in the same treatments in the years 2004-06. The area of one plot for harvest was 56 m$^2$.

Effects of the following factors were investigated: the date of ploughing to incorporate straw mulch and farmyard manure (in the autumn, the final 10 days of October, and next year in the spring, the second 10 days of May, with ploughing down delayed until the time of cabbage harvest), and soil mulching with straw (rye straw mulch at a rate of 5 t·ha$^{-1}$, a control where conventional farmyard manure at a rate of 40 t·ha$^{-1}$ was applied, a control without mulching or farmyard manuring). Straw was applied in the final 10 days of July to the mulched plots. Farmyard manure application in the combinations with autumn incorporation was performed in the autumn. In the treatments with spring ploughing down and the treatments without incorporation, farmyard manure was placed in spring in mid-May and ploughed down in both cases.

The effect of examined factors on the fresh mass and number of weeds was investigated. A direct effect of the examined factors on soil infestation was determined twice: in the final 10 days of April before spring soil tillage prior to cabbage cultivation, and in the final 10 days of October before cabbage harvest. A secondary effect was estimated in the first 10 days of April before soil tillage prior to onion cultivation and before onion harvest in the first 10 days of September. Weed infestation was determined by the quantitative-weighting method which involved determination of weed number and fresh mass in each plot. Samples were taken from an area selected by means of a 1x0.5 m square at three randomly selected places of each plot. In order to determine fresh mass, weeds were cut without roots and weighed. The weight was expressed per 1 m$^2$.

The total yield of cabbage (heads without outer leaves) and onion (bulbs after removal of leaves and roots) was measured during harvest.

The results of the experiment were analyzed statistically by means of the analysis of variance. Significant differences between treatments were assessed using Tukey Post-hoc test at p=0.05. Linear correlation coefficients were calculated in order to determine relations between weed infestation of the soil and yields of vegetables.

## Results and Discussion

### Differences in Weed Infestation of the Soil in the Consecutive Study Years

The fresh mass and number of weeds in red cabbage (Fig. 1) and onion (Fig. 2) in the consecutive study years differed significantly. Before spring soil tillage prior to cabbage cultivation and before cabbage harvest, the least amount of fresh mass and number of weeds were found in the warm and dry 2003, and both values were higher in 2004 and 2005 when higher rainfall was recorded. According to Radics and Bognár [18], in dry years straw mulching produced better results in tomato cultivation as far as weed control was concerned, as compared to a humid year. Changes in fresh mass and number of weeds prior to planting of cabbage seedlings and onion sowing followed the six-month rainfall pattern prior to weed infestation determination. No similar dependences were found before vegetable harvest.

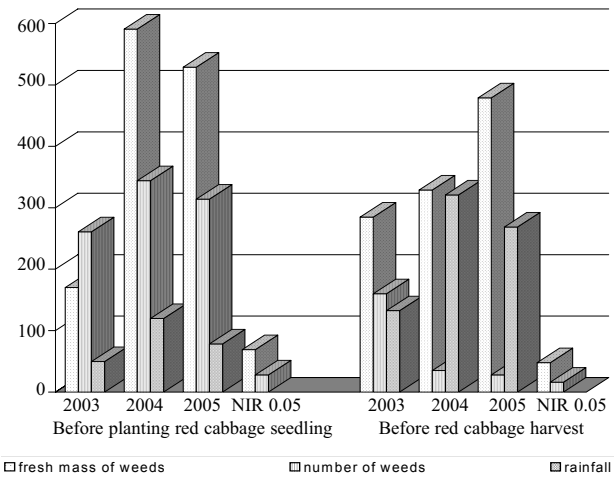


Fig. 1. Fresh mass [g·m$^{-2}$] and number [plants·m$^{-2}$] of weeds in red cabbage cultivation.

## The Effect of Straw Mulch on the Number of Weeds

The number of weeds before planting of cabbage seedlings on the soil left without ploughing down till spring was smaller compared with autumn-incorporated soil (Fig. 3). In turn, Błażewicz-Woźniak et al. [2] showed that the degree of onion field infestation with weeds depended on the kind of soil cultivation. On the basis of results obtained it was found that post-winter field infestation with weeds was significantly higher when no cultivation was applied (37.3 plants·m$^2$) as compared to the conventional plough-based cultivation (8.3 plants·m$^2$). The number of weeds in the straw mulched plots with autumn incorporation was significantly higher compared with the number obtained in the farmyard manure-fertilized treatment (by 10.6%). However, straw that had not been ploughed down (meant for spring incorporation or left as a mulch without ploughing down) significantly reduced the number of weeds in comparison with the values obtained for the farmyard manure-fertilized plots (by 15.9%) and control (10.0%). Teasdale [21] and Vidal and Baumann [23] claim that weed suppression can result from the mulch layer's ability to liberate substances, inhibiting development of some weed species. Weed-suppressing effect of straw mulch reported in studies can also result from a limited amount of light reaching the soil surface. According to Weber and Hryńczuk [24] (in Klümper [13]), germination of some weed species depends on the so-called light reaction which stimulates plant emergence. Cardina et al. [5] and Mohler [14] claim that lack of light makes weeds remain dormant in the top soil layer and, as a result, no infestation of crop plants takes place. In their studies Döring et al. [6] found no significant influence of straw mulching on the number of weeds. According to the authors, the doses of straw they examined (1.25 t·ha$^{-1}$, 2.5 t·ha$^{-1}$, 5 t·ha$^{-1}$) neither reduced nor enhanced weed infestation significantly. They attributed it mainly to the small amounts of straw applied. Hembry and Davies [9] found that weed growth still occurred at 20 t·ha$^{-1}$ of straw mulch, although with few weeds.

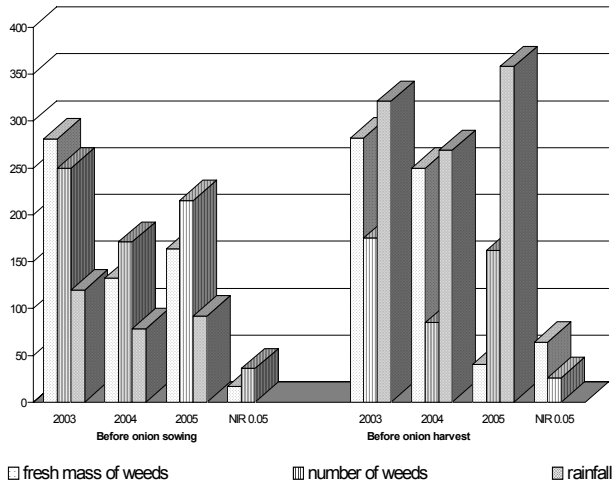


Fig. 2. Fresh mass [g·m$^{-2}$] and number [plants·m$^{-2}$] of weeds in the onion cultivation.

Before cabbage harvest the non-incorporated straw mulch significantly decreased the number of weeds compared with the control. Autumn or spring incorporation did not result in significant differences in the number of weeds between the straw-mulched treatments, farmyard manure-amended treatments and control. In turn, Błażewicz-Woźniak et al. [2] found that simplifications in soil cultivation associated with an application of mulching and abandoning pre-winter ploughing substantially increased the number of weeds in onion cultivation in comparison with the control where autumn incorporation was applied. In the studies by Döring et al. [6], in the initial period following straw mulch application, the number of weeds that germinated under mulch amounted to 15.6 plants·m$^{-2}$ and was higher compared with the unmulched plots (10.4 plants·m$^{-2}$). After 20 days, the number of germinated weeds in the mulched plots amounted to 24.4 plants·m$^{-2}$ and was over three times lower than that for the unmulched plots. It is also supported by Zagarozy [25], whose studies revealed that all organic mulches used in the experiment suppressed weeds, but the efficiency depended on the mulch layer thickness placed on the soil surface.

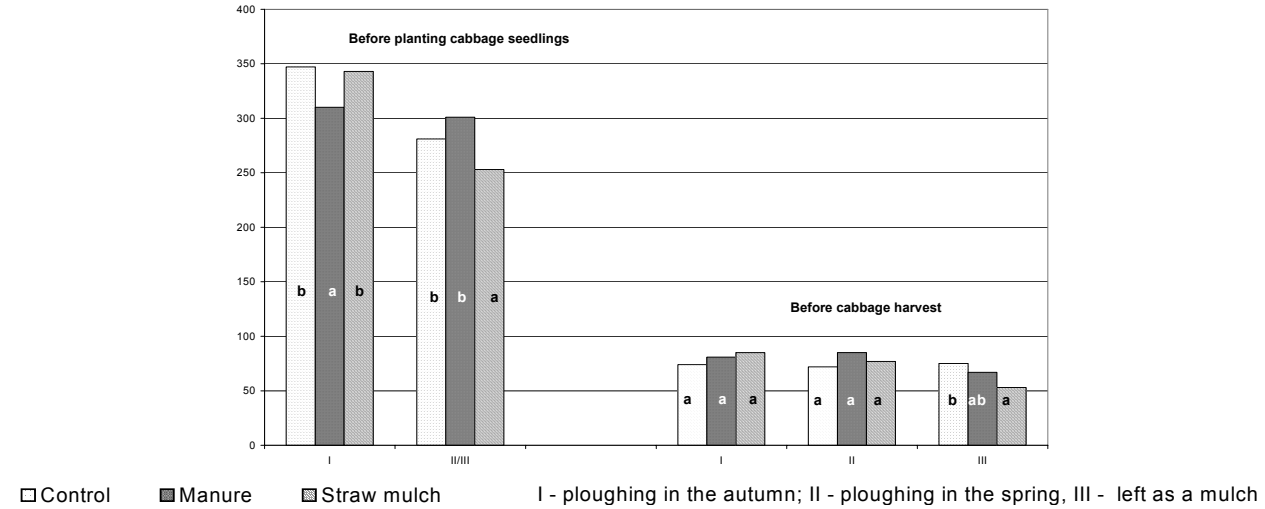


Fig. 3. Number of weeds in the red cabbage cultivation [plants·m$^{-2}$].
Mean from adjacent columns indicated this same letter does not differ significantly at p=0.05.

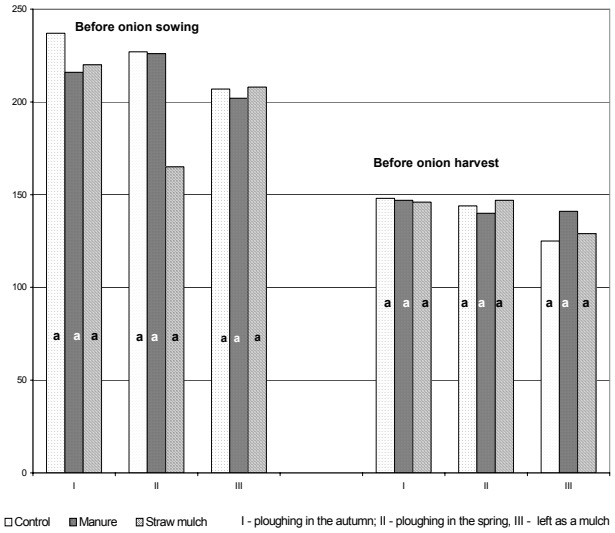


Fig. 4. Number of weeks in the onion cultivation [plants·m$^{-2}$]. Mean from adjacent columns indicated this same letter does not differ significantly at p=0.05.

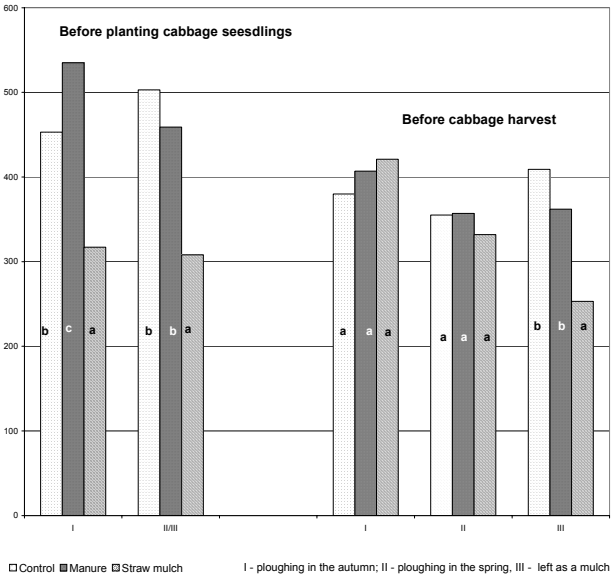


Fig. 5. Fresh mass of weeds in the red cabbage cultivation [g·m$^{-2}$]. Mean from adjacent columns indicated this same letter does not differ significantly at p=0.05.

Before onion sowing and harvest, the date of ploughing down and straw mulch had no significant secondary effect on the number of weeds (Fig. 4).

## Effect of Straw Mulch on Fresh Mass of Weeds

Prior to planting cabbage seedlings and before onion sowing, the predominant species on the experimental site were field pansy (*Viola arvensis* Murr.), shepherd's-purse (*Capsella bursa* pastoris) and common chickweed (*Stellaria media* (L.) Vill.). In most cases weeds were at seedling stage and the mass of one plant amounted to 1.42 g and 0.91 g, respectively.

The incorporation date and interaction of the investigated factors had a significant influence on the fresh mass of weeds (Fig. 5).

Fresh mass of weeds on the soil with autumn and spring mulch incorporation did not differ significantly when determined before cabbage planting. In turn, Kęsik and Błażewicz-Woźniak [11] and Bàrberi [1] have reported the necessity of performing pre-winter ploughing down as an important factor in weed control.

An interaction of ploughing date and straw mulching was found. The fresh mass of weeds in the straw-mulched plots with autumn incorporation was significantly lower compared with the mass obtained in the control and farm-

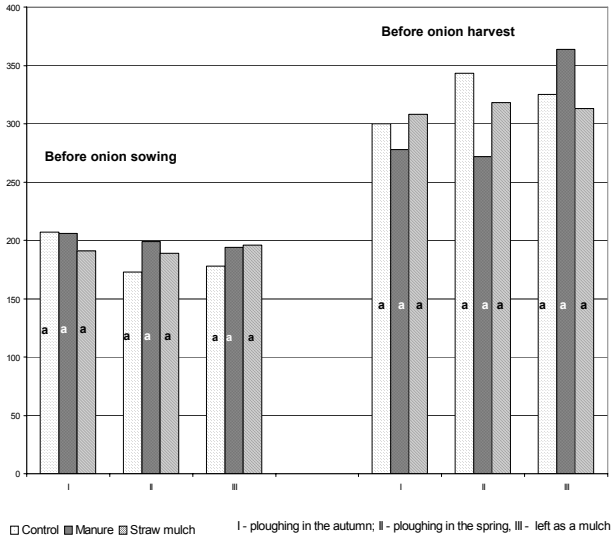


Fig. 6. Fresh mass of weeds in the onion cultivation [g·m$^{-2}$]. Mean from adjacent columns indicated this same letter does not differ significantly at p=0.05.

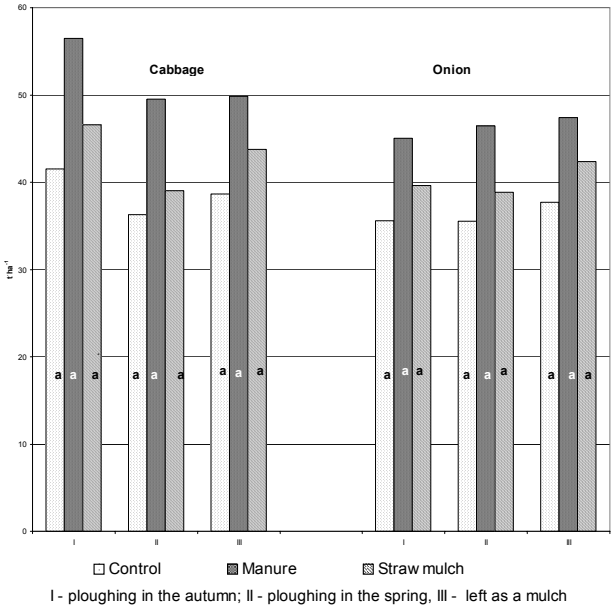


Fig. 7. The effect of straw mulch on vegetables total yield. Mean from adjacent columns indicated this same letter does not differ significantly at p=0.05.

yard manure-fertilized treatment (by 30.1% and 40.7%, respectively). Leaving straw mulch till cabbage harvest significantly reduced the fresh mass of weeds compared with the control (by 38.8%) and the farmyard manure-fertilized treatments with spring incorporation (by 32.9%). Other authors found that all organic mulches, including straw, reduce weed germination. Authors claim that a positive effect of mulches was particularly obvious in the period of intensive germination of weeds [10, 15]. According to Jodaugienė et al. [10,] organic mulches are particularly important in the first half of summer. In studies by the authors noted above, weed emergence was 3.5-14.1 times less in straw-mulched versus unmulched plots.

White goosefoot (*Chenopodium album* L.) and common chickweed (*Stellaria media* (L.) Vill.) were the predominant weed species before cabbage harvest. An average mass of one plant, amounting to 4.91 g, was significantly higher compared with the mass determined prior to planting of cabbage seedlings.

We found a significant interaction of the investigated factors with respect to the fresh mass of weeds.

The fresh mass of weeds determined prior to cabbage harvest in the straw-mulched treatment (with both spring and autumn incorporation of the mulch), the control and farmyard manure-amended treatment did not differ significantly. However, when straw mulch was retained on the soil surface without incorporation, the fresh mass of weeds was significantly lower compared with the control and farmyard manure application (by 38.1% and 30.1%, respectively).

The weeds species composition was different prior to onion harvest as compared to cabbage. The predominant species included shepherd's-purse (*Capsella bursa* pastoris), field pansy (*Viola arvensis* Murr.), common speedwell (*Veronica arvensis* L.) and scentless mayweed (*Matricaria inodora* L.). The mass of one plant averaged 2.23 g.

The investigated factors did not cause significant changes in the fresh mass of weeds before onion harvest (Fig. 6).

### The Effect of Straw Mulch on Vegetable Yields

The yield of cabbage and onion cultivated after straw mulch, irrespective of the date of ploughing down, was higher compared with the control and lower compared with farmyard manure. However, the differences between the means did not differ statistically (Fig. 7).

### Correlation between Weed Infestation and Vegetable Yields

The total yield of cabbage was significantly and negatively correlated with the number of weeds, and positively associated with their mass before cabbage harvest (Table 1). A negative relationship between cabbage yield and number of weeds probably resulted from the fact that under less favourable conditions, in terms of cabbage yield, the vegetable was less competitive against weeds.

Table 1. Coefficients of correlation between total vegetable yield and number and fresh mass of weeds before their harvest.

| Investigated parameters | Cabbage | Onion |
|---|---|---|
| Number of weeds | - 0.607* | 0.278 |
| Fresh mass of weeds | 0.537* | 0.156 |

* significant at p=0.05.

As a result, a higher numbers of weeds was found when cabbage yield was smaller. The conditions beneficial for plant growth favoured both the growth of weeds and cabbage, hence the positive correlation between the mass of weeds and total cabbage yield.

We found no significant correlation between onion yield and number and mass of weeds prior to onion harvest.

## Conclusions

Straw mulch utilization can be of importance on plant-oriented farms, as they experience problems with straw management and want to retain it in the field after harvest.

We found a beneficial limiting influence of straw mulch on weed pressure in the first year following mulch application. Weed infestation of the soil after straw mulch was significantly lower as compared to the farmyard manure-amended treatment and the unmulched control. Straw mulch, non-incorporated until cabbage harvest, significantly decreased the number and fresh mass of weeds in cabbage as compared to autumn- and spring-incorporated mulch. Straw mulching favourably influences yields, which is a significant advantage of the mulch. The cabbage and onion yields achieved after straw mulch were similar to the yield after farmyard manure applied at a dose of 40 $t \cdot ha^{-1}$.

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