Journal of Elementology ISSN 1644-2296

Kaniszewski S., Stępowska A., Sikorska-Zimny K. 2021.
*Effect of a plant-based fertilizer and red clover mulch on some soil properties and the yield and quality of sweet pepper.*
J. Elem., 26(3): 661-670. DOI: 10.5601/jelem.2021.26.3.2061



RECEIVED: 30 September 2020
ACCEPTED: 25 July 2021

**ORIGINAL PAPER**

# EFFECT OF A PLANT-BASED FERTILIZER AND RED CLOVER MULCH ON SOME SOIL PROPERTIES AND THE YIELD AND QUALITY OF SWEET PEPPER*

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**Abstract**

Plant-based fertilizer Ekofert, produced from red clover, and red clover mulch were compared with non-fertilized control and mineral N-fertilization (100 kg N $ha^{-1}$) in sweet pepper cultivation (2017–2019). The organic fertilizer was applied in doses of 4, 6 and 8 t $ha^{-1}$. Red clover mulch was applied at an amount of 70 t $ha^{-1}$ f.m. in split doses immediately after planting transplants and four weeks after its first application. The applications of the plant-based fertilizer Ekofert and red clover mulch increased the amounts of organic matter and organic carbon in the topsoil horizon, compared to the control treatment. Mineral nitrogen fertilization had a negative effect and reduced the amounts of organic matter and organic carbon in the soil, compared to the control and to the applied doses of the organic fertilizer and mulch. The organic and mineral fertilizers as well as red clover mulch increased the nitrogen content in the soil and sweet pepper leaves, compared to the non-fertilized control treatment. Ekofert and red clover mulch had a beneficial effect on the yield of sweet pepper. The highest yield of sweet pepper was obtained by mulching and at the highest dose of Ekofert (8 t $ha^{-1}$), while the dose of 6 t $ha^{-1}$ provided a yield similar to that obtained by the application of mineral nitrogen at a dose of 100 kg $ha^{-1}$. The results confirm potential use of the organic fertilizer Ekofert and soil mulching with red clover in organic and the so-called vegan organic horticultural production.

**Keywords**: plant-based fertilizer, red clover mulch, sweet pepper, soil organic matter.

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* This research received no external funding.

# INTRODUCTION

Intensive agricultural production associated with the use of mineral fertilizers and limited organic fertilization has led to degradation of the soil ecosystem. Continuous use of inorganic fertilizers alone causes deterioration of physical and chemical properties of the soil, a decrease in the organic matter content, acidification and environmental pollution. Thus, a combined application of inorganic fertilizers and organic manure constitutes an alternative system for sustainable and cost-effective management of soil fertility (Bhatt et al. 2019). Combined organic and mineral fertilization over long periods increases and stabilizes the humus content in soils (Tomov, Artinova 2005). Amendment of degraded soils with organic materials, e.g. compost, manure, crop residues and straw, can increase soil organic matter and restore the chemical, biological and ecological functionality. Also, amendments such as biochar and brown coal waste, which have very high C content, can be used to improve soil quality (Amoah-Antwi et al. 2020). Organic fertilizers and various types of organic amendments increase soil fertility and have a positive effect on plant growth and yield. The use of vermicompost and farmyard manure has been found to significantly affect the yield and quality parameters of garden cress under greenhouse conditions, while leonardite did not produce a positive effect (Akbudak, Zambi 2019). A positive effect of a bio-fertilizer produced by the Californian earthworm on the yield and growth parameters of pepper plants has been observed by Berova et al. (2010). Sweet pepper responds to organic and inorganic fertilizers under greenhouse conditions; however, NPK gave higher yield than chicken manure (Alhrout 2017). Organic fertilizers are of fundamental importance in organic production. Due to a certain health risk posed by fertilizers of animal origin, a group of producers of the so-called vegan organics exclude animal fertilizers and use only mineral or plant-based fertilizers (Alsanius et al. 2019). Kaniszewski et al. (2013) have shown that pelleted plant-based fertilizers produced from dry matter of red clover had a positive effect on the yield of celeriac. In experiments with onion (Kaniszewski et al. 2019), plant-based fertilizers produced from red clover and lucerne significantly increased onion production as compared to basic fertilization with compost. The efficiency of the organic fertilizers was equivalent to mineral fertilization at 100 kg N $ha^{-1}$ when applied at the lowest dose of 120 kg N $ha^{-1}$ and was significantly higher when applied at 180 and 240 kg N $ha^{-1}$.

The aim of the research conducted in 2017-2019 was to determine the impact of different doses of Ekofert organic fertilizer, produced from dried biomass of red clover, and organic mulch (fresh red clover) on the yield and quality of sweet pepper and some properties of the soil.

## MATERIAL AND METHODS

Field experiments were conducted at the Research Institute of Horticulture in Skierniewice, central Poland, on a sandy-loam soil. Pepper cv. 'Roberta $F_1$' plants were grown from transplants. The experiments were established in a randomized complete block design (RCBD) with four replications, each covering a 10 $m^2$ area.

The experimental factors were:

– pelletized organic fertilizer Ekofert, produced from dry red clover, applied at doses of 4, 6 and 8 t $ha^{-1}$;
– organic red clover mulch at 70 t $ha^{-1}$ f.m. applied in split doses immediately after planting the transplants and four weeks after its first application.

The effectiveness of the organic fertilizer and red clover mulch was compared with conventional mineral fertilization at an amount of 100 kg N $ha^{-1}$ applied as a split treatment at two doses, each of 50 kg N $ha^{-1}$, applied as pre-plant and side-dressing, and with the control plot without any additional fertilization. Pepper transplants were produced in a greenhouse. Seeds were sown in the middle of April to multi-cell trays (Vefia 96 filled with ready-made substrate "Potgrond H" from Klasmann-Deilman). The pepper seedlings were transplanted to a field in the middle of May in each year, spaced at 75 × 80 cm. The cultivated plants were regularly irrigated when soil water tension reached 0.03 MPa. A single water dose amounted to 20 mm.

In order to assess the yield and commercial quality, the fruit was harvested as it became coloured. In the last harvest, all fruits were harvested, regardless of the degree of colour development. The fruits were sorted in accordance with the applicable UNECE Standard for Sweet Peppers FFV-28 (2009).

Soil analyses of nitrate nitrogen (0-20 cm depth) were performed three times in the growing season (I – after planting, II – in the middle of the growing season, and III – after the harvest). The $N\text{-}NO_3$ and P concentrations were determined with the colorimetric method using a Scan Plus flow analyzer, and K was determined with an ICP plasma spectrometer. Fully ripened fruits (at least 20 fruits from each treatment for quality analysis) were harvested and immediately analyzed for ascorbic acid content (by the Thillmans method (ISO, 1984), total and reducing sugars were determined with Bertrand's method (Lati et al. 2017). Titratable acidity was determined by base titration in the presence of a colour indicator (Garner et al. 2008).

The results of the experiment were subjected to factorial analysis of variance with the significance of the means tested with the Newman-Keuls test at $P$=0.05.

# RESULTS

## N, P, K, organic matter, and organic C contents in soil

The organic plant-based fertilizer and red clover mulch significantly affected the organic matter and organic C content in the topsoil horizon after three years of application (Table 1). All the applied doses of the organic

Table 1

Organic matter, organic carbon and N-$NO_3$, P, K contents in the topsoil horizon at the end of plant growing season after 3 years of experiment

| Treatment | Organic matter (% d.m.) | C org. (% d.m.) | N-$NO_3$ (mg $dm^{-3}$) | P (mg $dm^{-3}$) | K (mg $dm^{-3}$) |
|---|---|---|---|---|---|
| Control | 2.69*b* | 1.43*b* | 26.7*b* | 135*a* | 56*b* |
| N-50+50 | 1.58*c* | 0.87*c* | 31.9*a* | 124*b* | 56*b* |
| Ekofert 4 t $ha^{-1}$ | 2.77*ab* | 1.52*ab* | 31.5*a* | 137*a* | 62*b* |
| Ekofert 6 t $ha^{-1}$ | 3.13*a* | 1.72*a* | 32.0*a* | 134*a* | 66*b* |
| Ekofert 8 t $ha^{-1}$ | 3.02*a* | 1.66*a* | 33.1*a* | 129*a* | 65*b* |
| Red clover mulch | 2.88*a* | 1.58*ab* | 32.7*a* | 139*a* | 136*a* |

Means followed by the same letter are not significantly different at $p = 0.05$.

fertilizer and mulching with red clover significantly increased the amounts of organic matter and organic C in the soil, compared to the control treatment and mineral nitrogen fertilization. The amounts of organic matter and organic C did not vary significantly between the different organic fertilizer doses and red clover mulch, and the highest content was found at the applied dose of 6 t $ha^{-1}$, which was 3.13 and 1.17% d.m. respectively. Fertilization with mineral nitrogen had a negative effect on the organic matter and organic C content in the soil and resulted in a reduction in these amounts, even compared to the control combination without fertilization. The amounts of organic matter and organic C in the treatment with mineral nitrogen were the lowest and amounted to 1.58 and 0.87% d.m., respectively. After three years of research, no significant differences were found in the nitrate nitrogen content between the applied doses of organic fertilizer and red clover, while a significantly lower concentration of N-$NO_3$ (26.7 mg $dm^{-3}$) was found in the control treatment. The phosphorus content was significantly the lowest (124 mg $dm^{-3}$) in the treatment with mineral nitrogen, but it did not vary significantly in the other treatments. The highest potassium content (136 mg $dm^{-3}$) was found in the treatment with red clover mulch, where it more than doubled the content in the other treatments (Table 1).

The results of soil analysis showed changes in nutrient availability during plant growth, depending on the fertilization treatments (Figure 1). The nitrate nitrogen content was the highest (34-40 mg $dm^{-3}$) in all plots at the beginning of plant growth, compared to the later data of soil analysis,

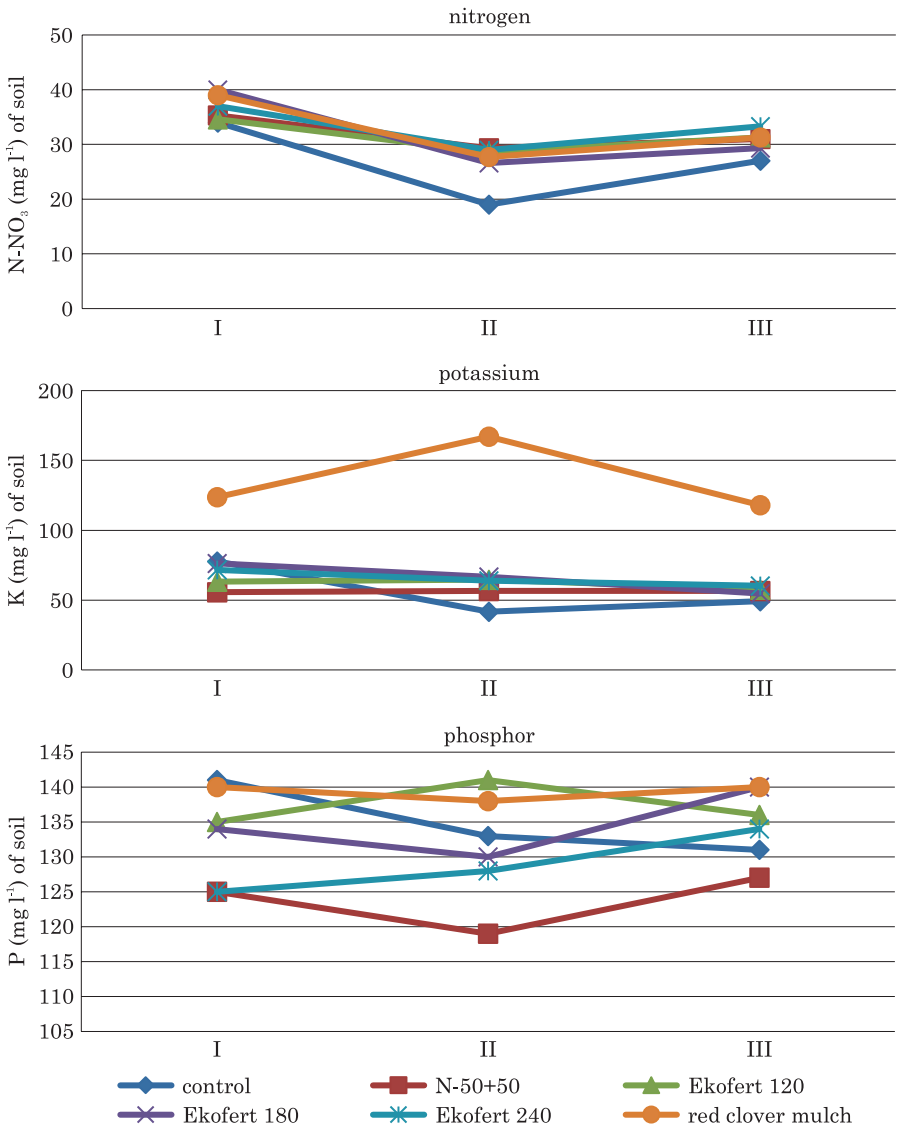


Fig. 1. $N\text{-}NO_3$, P and K content in the topsoil horizon (0-20 cm) during the growing season (average for 3 years of experiment)

and decreased especially in the middle of the growing season, during intensive growth of the plants. At the end of plant growth, when there was a limited nutrient uptake by the plants, the $N\text{-}NO_3$ content in the topsoil increased. The lowest $N\text{-}NO_3$ content was found in the non-fertilized control plots. The concentration of phosphorus did not change significantly during the growing season, but the lowest content was found in the plots with mineral nitrogen fertilization. The potassium content was the highest

(118-167 mg $dm^{-3}$) in the plots with red clover mulch, especially in the middle of the growing season; however, in the other treatments, the potassium content ranged from 42 to 76 mg $dm^{-3}$ and did not vary significantly during the growing season.

## NPK content in leaves

The use of mineral as well as organic fertilization and mulching with red clover increased the nitrogen content in pepper leaves, compared to the non-fertilized control treatment (Figure 2). The highest $N\text{-}NO_3$ content in the

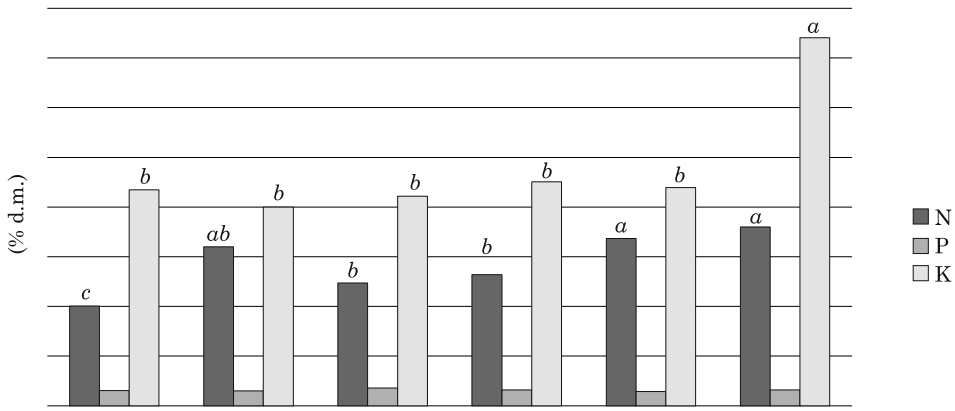


Fig. 2. Effect of plant-based fertilizer and red clover mulch on NPK content in sweet pepper leaves (average for 3 years of experiment)
Means followed by the same letter for element are not significantly different at $p = 0.05$

leaves was found in the treatments with red clover mulch, the highest applied dose of Ekofert (8 t $ha^{-1}$), and with mineral nitrogen application. Regarding the application of the lower doses of Ekofert (4 and 6 t $ha^{-1}$), the $N\text{-}NO_3$ content in the leaves was on a similar level. The concentration of phosphorus did not change significantly between the applied treatments. The significantly highest potassium content in the leaves (7.41%) was found in the treatment with red clover mulch. In the other treatments, the potassium content ranged from 4.0 to 4.5%, and did not vary significantly.

## Yield and fruit quality

On average for the three years of research, the applied fertilization treatments had a significant impact on the yield of sweet pepper (Figure 3). When using the Ekofert organic fertilizer, the increase in yield was favourably correlated with the doses of the fertilizer, and ranged from 31% to 85% compared to the control treatment. The highest pepper yield was obtained by mulching with red clover and at the highest dose of Ekofert (8 t $ha^{-1}$). The application of the organic fertilizer Ekofert at a dose of 6 t $ha^{-1}$ made it possible to obtain a yield of sweet pepper that was similar to one under

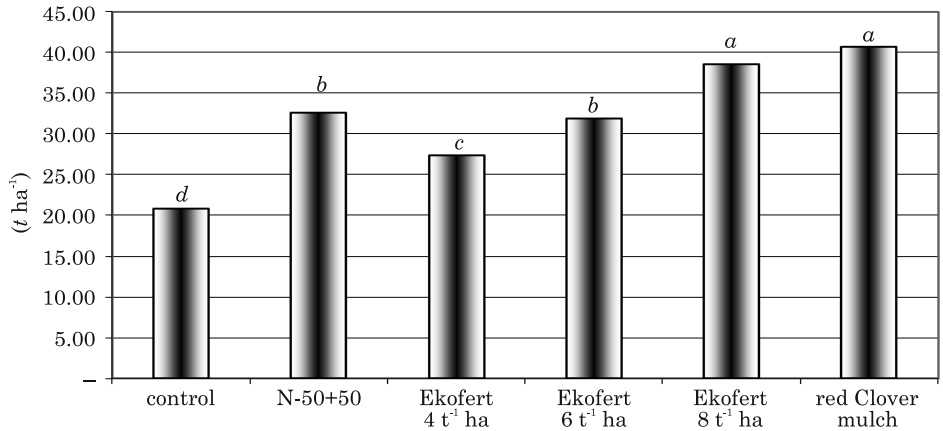


Fig. 3. Effect of plant-based fertilizer and red clover mulch on yield of sweet pepper
Means followed by the same letter are not significantly different at $p = 0.05$

the conventional mineral fertilization at 100 kg N ha$^{-1}$ applied in split doses (50+50 kg N ha$^{-1}$).

The use of the organic plant-based fertilizer Ekofert and red clover mulch had no significant effect on the vitamin C content in pepper fruits, although the highest content was found at the Ekofert dose of 6 t ha$^{-1}$ (Table 2). Mineral fertilization (50+50 kg N ha$^{-1}$) resulted in a decrease in the vitamin C content in relation to the control plots and to the applied organic fertilizer doses and clover mulch, although all the determined vitamin C contents were within the ranges reported by other authors for red pepper fruits (760-2400 mg kg$^{-1}$) – Howard et al. (1994), Ogunlesi et al. (2010). The lowest sugar content was also found in the treatment with mineral fertilization, but there were no differences in sugar content between the applied doses of the organic fertilizer, red clover mulching, and the control treat-

Table 2

Effect of plant-based fertilizer on some quality traits of sweet pepper

| Treatment | Ascorbic acid | | Total sugars | | Reducing sugars | | Titratable acidity | |
|---|---|---|---|---|---|---|---|---|
| | (mg kg$^{-1}$) | | (%) | | (%) | | mg kg$^{-1}$) | |
| | av. | SD | av. | SD | av. | SD | av. | SD |
| Control | 1401 | 32.3 | 5.18 | 0.01 | 4.88 | 0.04 | 1.7 | 0.1 |
| N-50+50 | 1184 | 8.0 | 4.48 | 0.03 | 4.35 | 0.36 | 1.8 | 0.1 |
| Ekofert 4 t ha$^{-1}$ | 1479 | 85.4 | 5.59 | 0.05 | 4.54 | 0.11 | 2.0 | 0.1 |
| Ekofert 6 t ha$^{-1}$ | 1704 | 92.5 | 5.79 | 0.03 | 4.56 | 0.13 | 2.0 | 0.1 |
| Ekofert 8 t ha$^{-1}$ | 1324 | 60.6 | 5.36 | 0.06 | 4.32 | 0.17 | 1.9 | 0.1 |
| Red clover mulch | 1561 | 22.5 | 5.46 | 0.03 | 4.09 | 0.11 | 1.9 | 0.2 |

av. – average, SD – standard deviation

ment; however, the determined values were slightly lower than those given by other authors (6.3–6.6%) (Kunachowicz et al. 2005). There were no differences in the amounts of reducing sugars in the pepper fruits and in titratable acidity between the treatments used. For both parameters, the obtained values were similar to those given by other authors (Kunachowicz et al. 2005, Shaha et al. 2013, Kwaśniewska-Karolak 2017).

## DISCUSSION

Organic fertilizers, as well as various types of organic amendments, increase the amounts of organic matter in the soil, improve the soil structure, increase water retention, nutrient availability, and provide better conditions for the growth of the root system (Bhatt et al. 2019, Amoah-Antwi et al. 2020). The results of the present study indicate that the application of the plant-based fertilizer, produced from dry red clover, and mulching with red clover increased the amounts of organic matter and organic carbon in the topsoil horizon, compared to the control treatment. Mineral nitrogen fertilization, on the other hand, had a negative effect and reduced the amounts of organic matter and organic carbon in the soil, compared to the control and the applied doses of the organic fertilizer and mulch. This confirms the results of Alimi et al. (2007), who found that mineral fertilizers enhanced the decomposition of soil organic matter, which leads to degradation of soil structure. Our results of soil analysis showed that the nitrogen content increased with increasing doses of the organic fertilizer Ekofert. The mulching with red clover also resulted in an increase in the nitrogen content and in a significant increase in the potassium content in the soil, which is related to the high concentration of this element in this plant. The nitrate nitrogen content was the highest at the beginning of plant growth and decreased in the middle of the growing season. At the end of plant growth, when there was a limited nutrient uptake by the plants, the $N\text{-}NO_3$ content in the topsoil horizon increased. The potassium content, on the other hand, was the highest in the middle of the growing season, which was associated with the application of the second dose of clover mulch. The concentration of nutrients in pepper leaves was closely correlated with the concentration of those nutrients in the soil. Similar results had been obtained in previous studies with celeriac and onion plants, where the decomposition of organic matter from the applied organic fertilizers increased the concentration of nutrients in soil and plant (Kaniszewski et al. 2013, 2019). Alimi et al. (2007), too, had reported that the use of organic fertilizers, especially the long-term use of manure, increased the nutrient content in the soil. The use of the organic fertilizer produced from dried clover and mulching with red clover had a beneficial effect on the yield of sweet pepper. The highest yield of sweet pepper was obtained by mulching and

at the highest dose of Ekofert (8 t $ha^{-1}$), while the dose of 6 t $ha^{-1}$ provided a yield similar to that obtained by the application of mineral nitrogen at a dose of 100 kg $ha^{-1}$. This confirms the potential of using plant-based organic fertilizers especially in organic vegetable cultivation, where mineral fertilizers cannot be used. Also, due to the potentially lower contamination risk, such fertilizers can be used in the so-called vegan organic horticulture, where animal organic fertilizers are excluded for consumers of vegan products (Alsanius et al. 2019). The use of organic fertilizers is also supported by the higher quality of sweet pepper fruits, expressed in higher concentrations of ascorbic acid and total sugars, compared to mineral nitrogen fertilization. Fruit firmness, pericarp thickness, pH and total soluble solids content showed higher values with the organic method, but these differences were not significant with respect to the conventional method (Del Amor 2006).

## CONCLUSIONS

Application of the plant-based fertilizer Ekofert, produced from dried biomass of red clover, and mulching with red clover increased the amounts of organic matter and organic carbon in the topsoil horizon, compared to the control treatment. Mineral nitrogen fertilization, on the other hand, had a negative effect and reduced the organic matter and organic C content. Application of increasing doses of Ekofert and mulching with red clover also resulted in an increase in the nitrogen content in the soil and sweet pepper leaves, compared to the non-fertilized control treatment. The higher amounts of organic matter, organic C, and nutrients in the soil caused by Ekofert application and mulching with red clover had a positive effect on the yield of sweet pepper. The highest yield of sweet pepper was obtained by mulching and at the highest dose of Ekofert (8 t $ha^{-1}$), while the dose of 6 t $ha^{-1}$ provided a yield that was similar to that obtained by the application of mineral nitrogen at the rate of 100 kg $ha^{-1}$. The use of organic fertilization and organic mulching also had a positive effect on vitamin C and total sugars content in pepper fruits, compared to mineral nitrogen fertilization.

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