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EFFECT OF IRRIGATION AND ORGANIC FERTILIZATION ON THE YIELD OF CRISPHEAD LETTUCE GROWN UNDER ECOLOGICAL CONDITIONS

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Abstract

The aim of the study conducted in the years 2014-2016 was to determine the effects of different irrigation systems and doses of different organic fertilizers on the yield of crisphead lettuce. The experiments were conducted in a certified organic field of the Research Institute of Horticulture in Skierniewice. The study compared micro-sprinkler irrigation, drip irrigation and the control combination (without irrigation). The fertilization combinations involved the use of compost at 30 t/ha, Ekofert L in a dose corresponding to 50 and 100 kg N/ha, Fertilan L in a dose corresponding to 50 and 100 kg N/ha, and the control (no fertilizer).

It was found that the use of irrigation in the first and third year of the study did not produce positive results, which was due to sufficient rainfall that fully satisfied the water requirements of lettuce plants. However, with a total rainfall not exceeding 80 mm (in 2015), the use of the irrigation systems had a significant impact on yield. Compared with the control, the irrigation with micro-sprinklers in 2015 increased the yield of lettuce by 35%, and in the case of drip irrigation by 40%.

The response of lettuce plants to the applied organic fertilization varied in the individual years of the study; however, of all the tested fertilization treatments, the use of compost at 30 t/ha produced the best yield-enhancing effect. Fertilization with the lucerne-based fertilizers resulted in an increase in yield, in relation to the control combination, in only one year of the study (2015).

The results showed that the organic fertilizers Ekofert L and Fertilan L were slow-acting fertilizers because their impact on the yield of lettuce, a plant with a short vegetative period, was relatively small. These fertilizers are more effective in the cultivation of species that have a long period of vegetative growth.

Keywords: organic cultivation, irrigation, fertilization, lettuce

INTRODUCTION

Organic methods of growing vegetables require extensive knowledge and experience because organic producers are deprived of the possibility of using plant protection products and synthetic fertilizers. Fertilization of organic crops, due to the very small selection of fertilizers approved for this type of production, is based mainly on the use of manure and compost. It should be noted, however, that the use of manure may carry the risk of vegetables becoming contaminated with bacteria that are dangerous to human health, such as *Escherichia coli* O157:H7. The bacteria can penetrate into the root system, from where they can be transported to the edible parts of plants, posing a serious threat to the health of consumers (Van Renterghem et al. 1991; Natvig et al. 2002; Salomon et al. 2002). On the other hand, G.S. Johannessen et al. 2004, based on the results of their research, have concluded that the use of manure does not cause bacteriological risks. The advantage of organic fertilizers is not only the ability to increase the amount of nutrients in the soil but also to increase its productivity by improving the physical, physico-chemical, chemical and biological properties (Edmeades, 2000, Hole *et al.* 2005, Gattinger *et al.* 2012). In a crop rotation system that includes the cultivation of papilionaceous plants (legumes), including small-seed perennials such as red clover and lucerne, and of annual legumes in pure stand or various mixtures, it is possible to achieve a satisfactory yield of organically grown crop plants (Maeder *et al.* 2002). Small-seed legumes (clovers and lucernes) harvested several times a year produce large amounts of green biomass rich in nutrients, especially nitrogen, potassium, calcium and microelements, and after drying and granulation can be a valuable fertilizer in organic vegetable production (Kaniszewski *et al.* 2013). Currently, granulated organic fertilizers are available for organic production, such as granulated manure or fertilizers produced from the biomass of plants of the legume (*Fabaceae*) family, e.g. Ekofert and Fertilan (Babik *et al.* 2015).

Fertilizers of this type also act significantly more slowly than mineral fertilizers and in that way plants are provided with a long-term access to nutrients. The rate of mineralization of organic fertilizers depends on environmental conditions (moisture, temperature).

The literature contains relatively little data on the irrigation of lettuce in open-field cultivation, and no such studies have been conducted under organic growing conditions. Lettuce plants, due to their poorly developed root system and a large surface area of the leaves, are very sensitive to water deficiency (Karczmarczyk and Nowak 2006). According to Kaniszewski (2005), lettuce plants require 80-120 mm of water.

The aim of this study was to determine the effects of irrigation and organic fertilization on the yield of crisphead lettuce.

MATERIAL AND METHODS

The study was conducted in the years 2014-2016 in a certified organic field (AGRO BIO TEST certificate of compliance) of the Research Institute of Horticulture in Skierniewice. The experiment was established in a two-factorial design with four replications. The study compared irrigation by means of micro-sprinklers, drip irrigation and the control combination (without irrigation). The fertilization treatments included applications of compost at 30 t/ha, Ekofert L in a dose corresponding to 50 and 100 kg N/ha, Fertilan L in a dose corresponding to 50 and 100 kg N/ha, and the control (no fertilizer). Both Ekofert L and Fertilan L are fertilizers produced on the basis of lucerne, which, thanks to the symbiosis with nodule-forming bacteria (rhizobia), fixes atmospheric nitrogen and is an excellent source of this nutrient for organic farms (Pietsch *et al.* 2007). In the case of Fertilan L, the technological process also involves additions of sheep wool to the dried lucerne. The compositions of the fertilizers are given in Table 1.

Table 1. Nutrient content of granulated organic fertilizers from clover and lucerne (Skierniewice 2012)

Type of fertilizer	Nutrient content (% DW)				
	N	P	K	Mg	Ca
Fertilan L	5.60	0.17	1.70	0.25	1.71
Ekofert L	3.47	0.23	3.10	0.23	1.63

Lettuce plants were grown in an open field after a cereal crop ploughed in the previous autumn. The lettuce cultivar used in the experiment was Vytalist from Vitalis Organic Seeds. The sowing of seeds, depending on the year, fell between the end of March and 20 April. The seeds were sown into tray multipots with a single cell capacity of 53 cm^3. The containers were filled with a certified organic substrate Potgrond Bio from Klasmann. After about four weeks, the seedlings were planted in a previously prepared field. The frequency of irrigation depended on soil moisture, assessed by measurements of soil moisture by means of tensiometers. Irrigation started when the water potential reached – 30 kPa. The irrigation was applied at the amount of 2 l per plant for drip irrigation and at the dose of 20 mm for micro-sprinkler irrigation. The surface area of an experimental plot was 3.68 m^2 (spacing between plants 35 × 35 cm). The lettuce crop was harvested after about two months and was assessed for total weight and marketable yield. The collected data were subjected to statistical analysis. The resulting mean values were compared using the Newman-Keuls test at $LSD_{\alpha = 0.05}$. Each time, the leaves were also analyzed for nitrate content.

RESULTS AND DISCUSSION

In all the years of the study, the highest yields of crisphead lettuce were obtained in the combination in which the plants were fertilized with compost at 30 t/ha, with the yield being significantly higher than in the other fertilization combinations in the first two years of the study (Figure 1). The use of the organic fertilizers Fertilan L and Ekofert L resulted in a significant increase in the yield of lettuce, in comparison with the control combination, only in one of the study years, whereas in the remaining years of the study the yield of lettuce was similar to that in the control combination. There were also no significant differences between the applied fertilizers, nor between the doses of these fertilizers. The small effect on the yield of lettuce of the organic fertilizers produced from leguminous plants and with the addition of sheep wool can be explained by a low degree of mineralization of this type of fertilizers, especially at a low temperature of the soil. This is evidenced by the low levels of $N\text{-}NO_3$ in the soil during the vegetative period as well as after the lettuce crop had been harvested (Figure.3, 4). The low concentrations of nitrate nitrogen in the lettuce leaves also provide evidence of a low uptake of this component by the lettuce plants (Figure 4, 5). Due to the short vegetative period and a low degree of mineralization, the influence of fertilization on yield was relatively small. The use of Ekofert in the cultivation of celeriac (root celery), which is a plant with a long growing season, had a significant effect on the yielding of that plant (Kaniszewski *et al.* 2013).

The response of lettuce plants to irrigation varied across the years of the study. In the first and third year of the study, due to the large amount of rainfall during the lettuce growth period, which amounted to 120 and 121 mm, respectively, the irrigation systems were activated only a few times (Table 2). At such a high level of precipitation, the crop yields were not dependent on the irrigation systems (Figure 2). According to Kaniszewski (2005), the demand of lettuce plants for water is in the range from 80 to 120 mm, and that is why in this study drip irrigation was found to have no effect on the yield of lettuce, and irrigation by means of micro-sprinklers even resulted in a significant reduction in yield.

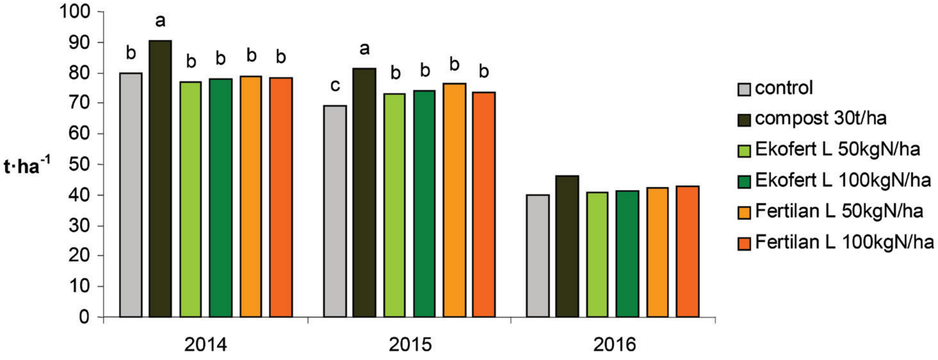

Figure 1. Effect of organic fertilization on the yield of crisphead lettuce

Table 2. Total rainfall and mean air temperature during the growing of lettuce.

Meteor. data	Growing period								
	2014			2015			2016		
	28-30 Apr	1-31 May	1-26 Jun	25-31 May	1-30 Jun	1-23 Jul	18-31 May	1-30 Jun	1-5 Jul
Total rainfall (mm)	0	91	29.2	9.6	38.6	29.8	8.4	96.2	16.2
Mean temp. (°C)	14.73	14.25	16.35	14.24	17.35	20.78	18.57	19.03	20.15

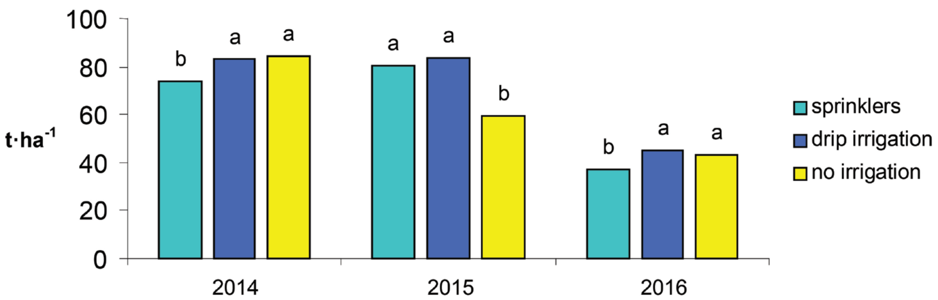

Figure 2. Effect of irrigation on the yield of crisphead lettuce

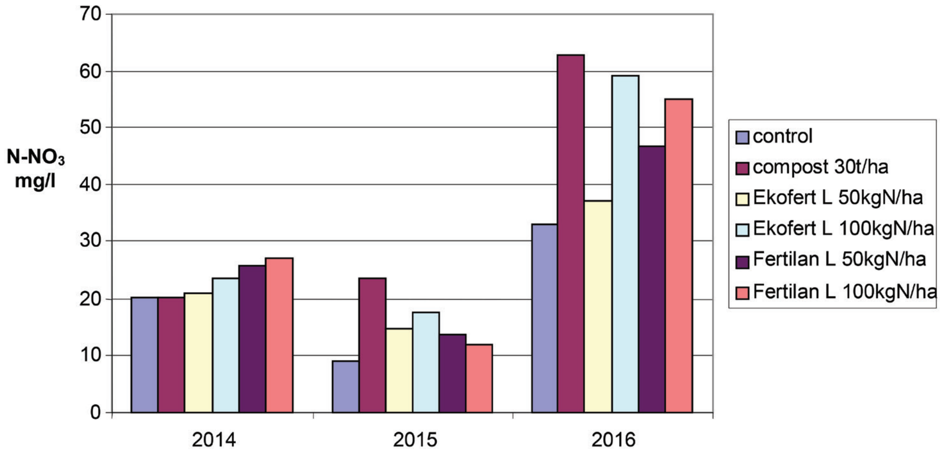

Figure 3. Effect of fertilization on the N-NO_3 content of the soil during the vegetative period

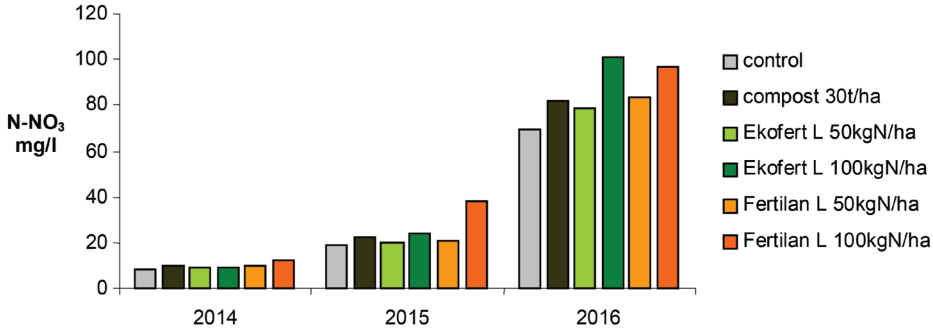

Figure 4. Effect of fertilization on the N-NO_3 content of the soil after the lettuce harvest

In the second year of the study, in which the amount of rainfall during the growing period of lettuce was 77 mm, irrigation caused a significant increase in yield for both irrigation systems in comparison with the control combination. The increase in yield under the influence of micro-sprinkler irrigation was 35%, and in the case of drip irrigation 40%.

In order to determine the levels of minerals in the soil and the extent of decomposition of the applied fertilizers, chemical analyses of soil samples were performed at two times after fertilizer application. It became evident that the rate of mineralization and the levels of nitrogen in the soil, particularly during the first two years of the study, were very low (Figure 3). The N-NO_3 content in the soil during the vegetative period in the first two years of the study did not exceed 30 mg in 1 litre of soil. In the last year, in which higher temperatures prevailed, the nitrate nitrogen content in the soil was found to be higher due to the mineralization of the organic fertilizers. However, this did not affect lettuce yields.

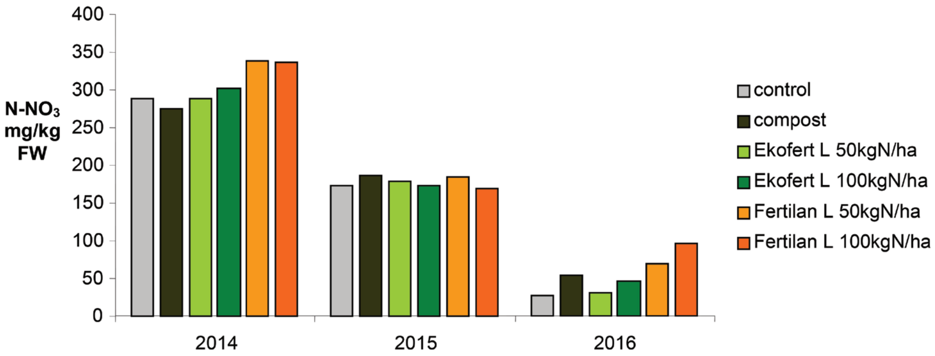

Figure 5. Effect of fertilization on the N-NO_3 content of lettuce leaves

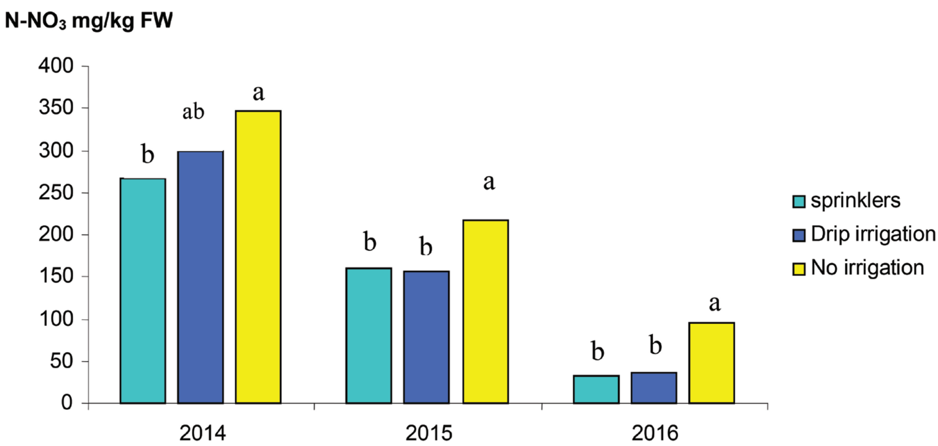

Figure 6. Effect of irrigation on the N-NO_3 content of the lettuce leaves

After the harvest, samples of plant material were also collected for chemical analyses to determine the levels of nitrates in them. The highest permissible level of these compounds according to the EC Commission Regulation No. 1881/2006 for crisphead lettuce grown in an open field is 2000 mg/kg FW. Regardless of the type of the fertilizer used and the irrigation system, the NO_3 – concentration in the leaves was very low and did not exceed 400 mg per kg of fresh weight. The influence of the applied fertilizers on the nitrate content was small, whereas irrigation decreased the levels of nitrates in comparison with the control combination.

SUMMARY

The most effective in the growing of crisphead lettuce proved to be the use of compost at 30 t/ha. The fertilizers Fertilan L and Ekofert L, due to slow mineralization, had a considerably lower yield-enhancing effect compared with compost.

Of the two irrigation systems used, better results were obtained with drip irrigation. Irrigation by means of micro-sprinklers in the years with high amounts of rainfall caused a decrease in the yield of lettuce.

There were no significant differences in the $N\text{-}NO_3$ content of the soil and lettuce leaves between the fertilizers used, nor between their doses. Irrigation decreased the $N\text{-}NO_3$ content of the lettuce leaves.

Mineralization of organic substances contained in the tested fertilizers is a long-term process so that it can be difficult to take full advantage of their nutritional potential when growing crops with a short vegetative period.

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