SEWAGE SLUDGE AS NUTRIENT SOURCE FOR BIOENERGY CROPS

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Abstract

Sewage sludge is rich in organic matter, and plant nutrients such as nitrogen, phosphorus and potassium. Nevertheless, using sludge as fertilizer for crops to produce food or feed is limited due to the presence of trace contaminants such as heavy metals. Therefore, the aim of this study was to investigate the use of sewage sludge as a nutrient source for bioenergy crops such as fibre hemp, oilseed rape and white lupin. Specific attention is paid to the biomass accumulation and the quality of the plant material as well as the ability of the crops to take up the heavy metals from soils in order to ensure that the amount of pollutant does not cumulate.

Fibre hemp (*Cannabis sativa* L.) cv. Uso, oilseed rape (*Brassica napus* L.) cv. Wildcat and white lupin (*Lupinus albus* L.) cv. Amiga were sown in 5-L pots in a greenhouse. Three potting mixes were used: a standard peat-based potting compost with 50% sludge, sludge with peat (50%:50% by weight), or 100% sludge, and a constant mass of 666 g potting mix per pot. Dry weight of plants and leaf area were measured four times during the growth of fibre hemp and oilseed rape and at maturity of white lupin. Net photosynthesis and leaf temperature of plants were measured three times. Ash content and elemental analysis was made from samples collected at harvest.

Sewage sludge application significantly affected most parameters measured. In fibre hemp, maximum dry weight, leaf area and photosynthesis values were obtained from the sludge – peat treatment. In oilseed rape, the maximum values of dry weight of plant, leaf area, photosynthesis, number of siliques per plant and number of seeds per plant were obtained from the 100% sludge treatment. However, the highest number of branches per plant, weight of siliques per plant, seed weight per plant and whole plant weight were obtained from the sludge – peat treatment. In white lupin, the sludge – peat treatment resulted in highest net photosynthesis, number of pods per plant, number of seeds per plant and whole weight plant at harvest. Highest sludge application resulted in highest heavy metal concentration in plant material of fibre hemp and white lupin. However, high heavy metal concentration in oilseed rape were obtained when sludge was mixed with peat.

It is concluded that sewage sludge is suitable for use as a nutrient source for bioenergy crops studied. In future experiments we will estimate the optimum level of sewage sludge for each one of these crops and determine its potential for use in field conditions.

Keywords: oilseed rape, white lupin, fibre hemp, sewage sludge, biomass, heavy metal

Introduction

Sewage sludge is rich in organic matter and plant nutrients such as nitrogen, phosphorus and potassium. Nevertheless, using sludge as fertilizer for crops to produce food or feed is limited due to the presence of contaminants such as heavy metals. Many studies have been done on the effect of sewage sludge as fertilizer on yield of plants for food or feed. In this study we focus on the utilization of sewage sludge as source of nutrients for bioenergy crops. Kauthale et al. (2005) found that minerals in organic matter in sewage sludge seem to have some benefits for growth and yield of crops. Quantitative and qualitative composition of sewage sludge is very complicated, it is rich in organic matter, macroelements (N, P, K, Mg, S) and other microelements necessary for plants and soil fauna (Kosobucki et al. 2000). However, the levels of heavy metals found in sewage sludge are considerably higher than in typical agricultural land (Sloan et al. 1998). Significant accumulation of these metals in food crops may lead to potential health problems for the consumers (Richards et al. 1998).

Many researchers concluded that sewage sludge has some features effects on agriculture. Snyman et al. (1998) and Delgado et al. (2002) confirmed that it is possible to use sewage sludge as fertilizer which led to increase in biomass and yield of plants. Also, Delgado et al. (2002) reported that toxic effects were not observed from heavy metals in the plants. In addition, Aggelides and Londra (2000) confirmed that sludge application improved the physical, chemical and biological properties of soil. Sewage sludge can be used as a valuable source of plant nutrients to substitute the commercial fertilizer (Richards et al. 1998; Christodoulakis and Margaris 1996). Increasing sludge rates increased significantly the growth parameters, and the concentrations of Pb, Cd, Ni, and Cr in grains due to sludge application were generally higher than the normal concentrations values (Amin and Sherif 2001). Some toxic metals trace elements from sewage sludge can be stored in plants and contaminate the food chain (Juste et al., 1995).

Therefore, the aims of this study are to investigate the use of sewage sludge as a nutrient source for bioenergy crops and to analyse the role and translocation of heavy metals in these crops (fibre hemp, oilseed rape and white lupin). Specific attention is paid to the impact on biomass formation and the quality of the material as well as the ability of the crops to take up the heavy metals from soils in order to ensure that the amount of polluting agents does not increase.

Materials and Methods

Plant material and growth conditions

Oilseed rape (*Brassica napus* L., cv. Wildcat), fiber hemp (*Cannabis sativa* L., cv. Ronaldinio) and white lupin (*Lupinus albus* L., cv. Amiga) were grown under greenhouse conditions at the University of Helsinki, Finland. Seeds of oilseed rape, white lupin and fiber hemp were sown on 4.12.2008, 5. and 25.2.2009, respectively, in 5-L pots containing 3.333 kg soil. There were three different sludge treatments, as follows: 666 g sludge (H SL), 333 g sludge (L Sl) and 333 g sludge with 333 g peat (Sl+P). Four white lupin seeds, fifteen oilseed rape seeds and six hemp seeds were sown in the pots. The number of seedlings per pot was reduced to ten in oilseed rape, one in white lupin and three in fibre hemp, respectively.

Measurements

Biomass was determined four times during growth period of oilseed rape and fiber hemp and once at harvest for white lupin. Plant parts were separated into leaves, stems and flowers and weighed immediately after sampling. After drying for 72 h at 65 °C, samples were weighed again. Leaf area was measured with LI-3000-A (LI-COR Inc., USA, Lincoln, Nebraska, USA) portable leaf area meter. Leaves were considered to be dead if over 50% of the foliage was yellow or brown.

Heavy metals and metalloid were analysed from the dried plant material at MTT Agrifood Research, Finland. Dried sample was digested in nitric acid (p.a.). Heavy metal were determined by ICP-OES. Arsenic (As) was determined by ICP-MS.

Results

The highest fresh and dry weights per plant were obtained when sludge was added as a mixture with peat (50% w: 50% w). However, there were no significant differences between high sludge (100%) and

sludge as mixture with peat on dry weight obtained at 30, 45 and 60 days after sowing (DAS). The low sludge application (50%) resulted in the lowest fresh and dry weigh.

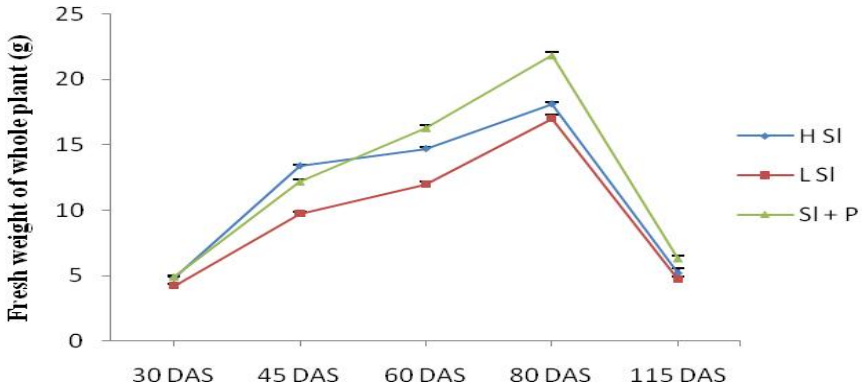

Fig. 1a. Effect of sludge application on fresh weight accumulation of oilseed rape. Data are means ± SE, n=4.

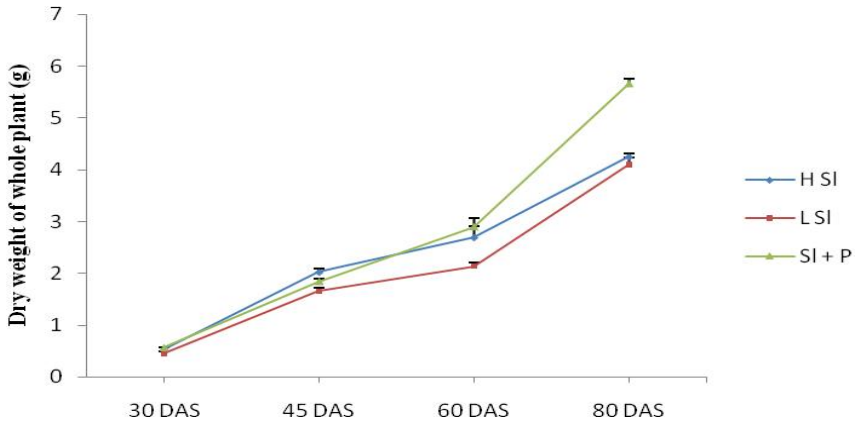

Fig. 1b. Effect of sludge application on dry weight accumulation of oilseed rape. Data are means ± SE, n=4.

The highest sludge application resulted in the highest leaf area, although there were no significant differences between high sludge and sludge mixed with peat on leaf area at 30 and 45 DAS (Fig. 2).

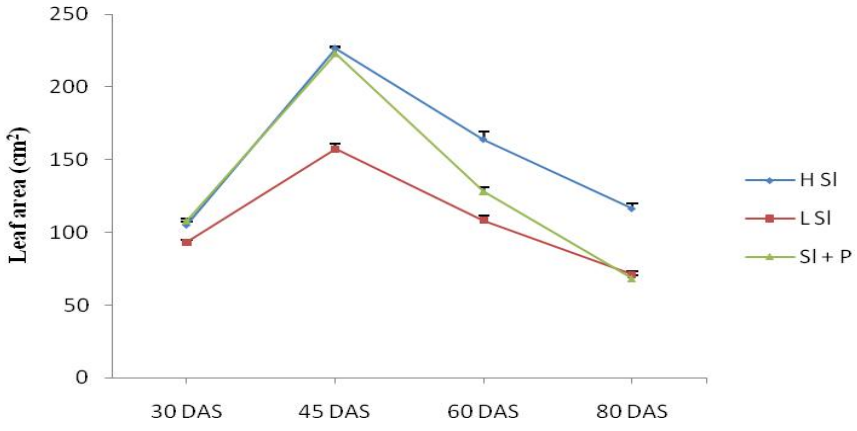

Fig. 2. Effect of sludge application on leaf area development of oilseed rape. Data are means ± SE, n=4.

Highest concentration of As at 60 and 115 DAS were obtained by sludge with peat application. On the other hand, there were significant differences between sludge treatments on cadmium (Cd), nickel (Ni) and copper (Cu) at 60 DAS. Increasing the amount of sludge in the mix up to 666 g per pot resulted in an increase in the chromium (Cr), Ni and Cu concentration of plants. In contrast, Cd and zinc (Zn) concentrations were highest when sludge was mixed with peat.

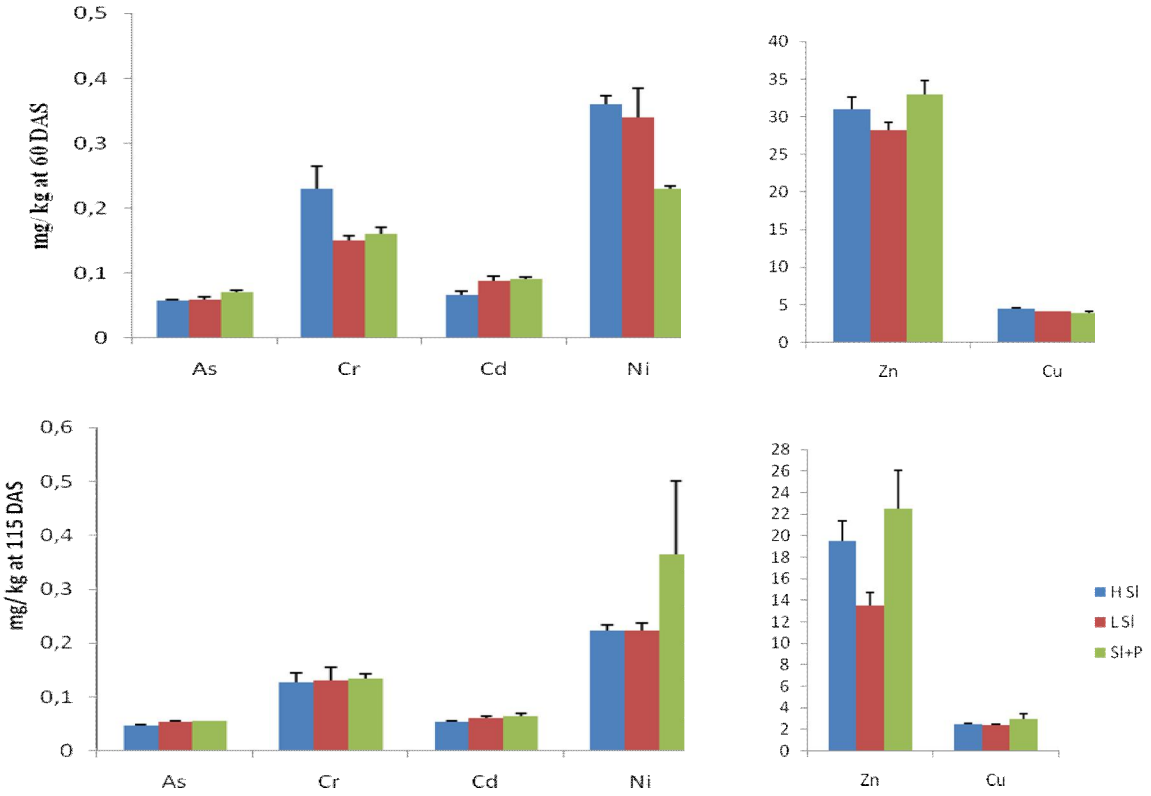

Fig. 3. Effect of sludge application on heavy metal and metalloid concentrations in oilseed rape plants. Data are means ± SE, n=4.

Conclusion

It is concluded that sewage sludge can be used as a nutrient source for bioenergy crops, such as fibre hemp, oilseed rape and white lupin. Future experiments will estimate the optimum level of sewage sludge for each one of these crops and determine its potential for use in field conditions.

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