Field Crops Research 133 (2012) 130–138

Contents lists available at SciVerse ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Nitrogen and phosphorus leaching losses from potatoes with different harvest times and following crops

Angelika Neumann, Gunnar Torstensson, Helena Aronsson*

Swedish University of Agricultural Sciences, Department of Soil and Environment, PO Box 7014, 750 07 Uppsala, Sweden

ARTICLE INFO

Article history:
Received 19 August 2011
Received in revised form 14 March 2012
Accepted 14 March 2012

Keywords:
Leaching losses
Nitrogen
Phosphorus
Potato
Catch crop

ABSTRACT

A 3-year field study (2007–2009) was conducted in separately tile-drained plots on a sandy soil in southwest Sweden to determine nitrogen (N) and phosphorus (P) leaching losses from potatoes to the drainage system. Different types of potatoes were grown and harvested at different times followed by different crops in order to identify the potato type/following crop system with the lowest risk of N and P leaching losses. Accumulated annual amounts of N and P lost to drainage between May (potato planting) and the following April varied between 13 and 72 kg N ha^{-1} and 0.04 and 0.24 kg P ha^{-1} depending on treatment and year. P leaching losses from this particular soil were low and differences between potato types not distinct, but there were significant differences between years. Abnormally high precipitation in summer 2007 led to significantly higher P leaching losses than in other years. N leaching losses were also higher in 2007, but differences between potato types were found in all years. Despite the high mineral soil nitrogen content (N_{min}) after harvest in June, early potatoes (EP) with oilseed radish (oil) as catch crop showed the lowest N leaching losses of all potatoes. Potatoes harvested in August (table potato; TP) and September/October (late potato; LP) followed by triticale (tri) sown in October showed the highest leaching losses. Thus under current climate conditions in Sweden, oilseed radish after EP is a suitable catch crop for N, while triticale sown in October is ineffective in preventing N leaching after potatoes. The late harvest of starch potatoes (SP) did not allow establishment of a following crop. However, SP showed lower N leaching losses than TP + tri and LP + tri due to lower residual N_{min} in deeper soil layers, low temperatures after harvest decreasing soil N mineralisation and higher C:N ratio of the potato haulm leading to lower N mineralisation potential. As a mean of all years, N leaching losses during and after EP + oil and SP were similar to those from the reference crop spring barley (SB), whereas TP + tri and LP + tri require countermeasures against N leaching.

1. Introduction

Potatoes often receive high amounts of N fertiliser which, combined with a shallow root system and irrigation on sandy soils, pose a high risk of N leaching losses (Errebhi et al., 1998). These losses can be up to 50% of the added N (Machado et al., 2010). High N leaching losses from potatoes have been reported in several studies from not only Sweden but also from other countries (e.g. Shepherd and Lord, 1996; Ünlü et al., 1999; Gasser et al., 2002; Torstensson et al., 2006; Arriaga et al., 2009; Shrestha et al., 2010). However, P leaching losses from potatoes have not been studied as intensively. Considering that P fertiliser recommendations for potatoes in Sweden are high (Ekelöf, 2007) and that the sandy soils used for potato production show low P sorption capacity and shallow groundwater levels (Börling, 2003), P leaching losses from potatoes may also be high.

Nutrient losses from agriculture can cause eutrophication of surface waters. For example, the Baltic Sea is regularly subjected to severe outbreaks of algal blooms due to eutrophication with N and especially P. In Sweden, agricultural activities are estimated to be responsible for 47% of the total-N load (SwEPA, 2008a) and 51% of the total-P load (SwEPA, 2008b) from anthropogenic sources to the Baltic Sea. A widespread countermeasure to N leaching losses from agricultural land in Scandinavia is to grow a catch crop after harvest of the main crop. After late potatoes are harvested, however, it can be difficult to establish an efficient catch crop. In addition, catch crops may even increase P leaching losses (Miller et al., 1994).

A number of different cultivars and types of potatoes are grown for different purposes. These require specific amounts of N fertiliser,

Abbreviations: EP, early potato; LP, late potato; LSD, least significant difference; N, nitrogen; N_{min}, mineral soil nitrogen (NO_3-N + NH_4-N); oil, oilseed radish (*Raphanus sativus* ssp. oleiformes); P, phosphorus; SB, spring barley; SP, starch potato; tot-N, total nitrogen in drainage water (NO_3-N, NH_4-N and organic N); tot-P, total phosphorus in drainage water (PO_4-P + rest-P); TP, table potato; tri, triticale (*X Triticosecale* Wittmack).

* Corresponding author. Tel.: +46 18 672466; fax: +46 18 672795.
E-mail address: Helena.Aronsson@slu.se (H. Aronsson).

0378-4290/$ – see front matter
doi:10.1016/j.fcr.2012.03.011

have different harvest dates and enable different following crops. It is therefore important to quantify N and P leaching losses from different potato cropping systems in order to evaluate the need for alternative management practices to alleviate leaching losses which may occur with different potato varieties and harvest dates. This study determined the extent and timing of N and P leaching losses from four commonly used potato types in Sweden that were combined with different catch crops: early potatoes and table potatoes (for direct consumption), late potatoes (for consumption after storage) and starch potatoes (for industrial use). Early potatoes are harvested in July which enables the immediate sowing of a catch crop. For early sowing dates oilseed radish has become a common catch crop, because it has a positive effect on counteracting root-knot nematodes and is also known as an efficient N catch crop, as it significantly reduces residual N_{min} (Thorup-Kristensen, 1994). However, Miller et al. (1994) reported that oilseed radish may leach about 30% of biomass P. Table and late potatoes harvested in August and September/October, respectively, are commonly followed by a winter cereal. Winter cereals are known to have a shallow root system in the year of sowing (Thorup-Kristensen et al., 2009), so considerable amounts of N can be lost through leaching during the drainage period (Johnson et al., 1997; Dreymann, 2005). However, winter rye did not increase P leaching losses in experiments with repeated freeze–thaw cycles in a pot study by Bechmann et al. (2005). Starch potatoes are harvested too late to allow a following catch crop to be sown in the year of harvest under Swedish climate conditions. Residual N_{min} after the harvest of starch potatoes can therefore be assumed to be at an increased risk of being transported into deeper soil layers and lost through the drainage system during winter. In order to compare the quantities of nutrients leached from potatoes in this study we used spring barley as a reference crop. Model estimations of N and P leaching losses from arable land in Sweden indicate that N and P leaching in spring barley are similar to mean average leaching losses (SwEPA, 2005).

The objectives of the present study were: (i) to monitor N and P leaching losses from different potato type/following crop systems in comparison to spring barley and (ii) to study the suitability of common following crops after potatoes for reducing mineral soil N and the risk of N leaching losses without increasing the risk of P leaching losses.

2. Materials and methods

2.1. Experimental site

The study was carried out during three years (2007, 2008 and 2009) on the experimental farm Lilla Böslid in south-west Sweden (56°35′N, 12°56′E). The region has a long-term average annual temperature of 7.2 °C and annual precipitation of 803 mm (Halmstad 1961–1990). All three years of the study showed higher mean annual temperatures than the long-term average (2007 and 2008: 8.7; 2009: 8.0 °C) and there were differences between years in annual precipitation, with receiving more than the mean annual precipitation in 2007 (965 mm) and less in 2008 (633 mm) and 2009 (613 mm). The summer of 2007 was characterised by unusually high rainfall (724 mm) during the main crop growth period (May–September), while the other two summers received only half that amount (2008: 340; 2009: 341 mm).

The experimental site was established in 2002 and consisted of 36 separately tile-drained plots, each 320 m^2. The tile drains are placed at 0.9 m depth, which is common practice in this region, where groundwater levels often fluctuate between 0.7 and 1.5 m depth. The soil, a Haplic Phaeozem (WRB soil classification system), consists of 88% sand, 5% silt and 7% clay in the topsoil (0–0.3 m depth) and 99% sand and 1% clay in the subsoil (0.3–0.9 m depth). Soil chemical analyses in 2005 showed an organic matter content of 4.9% and a pH_{H_2O} value of 6.1. Texture analyses were performed with a combination of sieving (for particles >0.06 mm) and pipette methods (for finer particles). The amount of ammonium lactate-soluble P (Egnér et al., 1960) in the topsoil was 12.8 mg per 100 g dry soil, which indicates that this soil is rich in plant-available P. The degree of P saturation was 21%, which means that the P sorption capacity may be considerable, resulting in reduced risk of P leaching. The degree of P saturation was calculated as ammonium lactate-soluble P divided by the sum of ammonium lactate-soluble Fe and Al (140 and 540 mg per 100 g dry soil, respectively).

2.2. Experimental design and management practices

Four different types of potatoes (*Solanum tuberosum* L.) were studied in terms of N and P leaching related to harvest time and following crop. The preceding crop for all types of potatoes was spring barley (*Hordeum vulgare*) and the soil was ploughed in November/December. Planting dates for the potato types, potato harvest, sowing of the following crop, ploughing, fertilisation and chemical kill-off are given in Table 1. Early potatoes (EP; 2007 and 2009: var. Solist; 2008: var. Rocket) were harvested in June/July for direct consumption and followed by oilseed radish (oil; *Raphanus sativus* ssp. oleiformes; 60–90 seeds m^{-2}). To be efficient against root-knot nematodes (*Meloidogyne hapla*), oilseed radish needs to be incorporated into the soil. This was done in November/December in the present study. Table potatoes (TP; var. Faxse) were harvested in August, also for direct consumption. The following crop triticale (tri; *X Triticosecale* Wittmack; var. Fidelio; 500 seeds m^{-2} in 2007 and 2009, 340 seeds m^{-2} in 2008) was sown after TP in September/October. Late potatoes (LP; var. Sava) were harvested in September/October for storage and were also followed by triticale (500 seeds m^{-2} in 2007 and 2009, 560 seeds m^{-2} in 2008). Before the sowing of all following crops, the soil was harrowed to a depth of 2 cm. Potato grown for starch production (SP; var. Kuras) was not followed by a crop in the same year of harvest. All treatments containing potatoes had three replicates and were grown in a randomised block design on different blocks each year, using all 36 plots at the site. Spring barley (SB; *Hordeum vulgare*; 2007 and 2008: var. Prestige; 2009: var. Henley), grown randomly in three replicates on one of the other blocks, was taken as a reference crop. The SB straw was left on the soil which remained bare (without a following crop) and undisturbed until it was ploughed with a mouldboard plough at a tillage depth of 0.23 m in November/December.

Fertilisation with N, P and K was carried out according to regional common practice before potato planting or SB sowing by broadcasting N–P–K fertiliser 8–5–19. A second N dose was given to TP (calcium nitrate, 15.5% N), LP and SP (calcium ammonium nitrate, 27% N) in June (also broadcasted). The total amounts of N applied to the potatoes are shown in Table 1. All potatoes were supplied with 44 kg P ha^{-1}. The K dose applied to potatoes was 165, 240, 330 and 390 kg K ha^{-1} for EP, TP, LP and SP, respectively, while no P and K were applied to SB or following crops. The potatoes were irrigated each year in late May or June, with 20 mm in 2007 and 2008 and 40 mm in 2009. Weeds and infections of *Phytophthora infestans* were chemically controlled in all years. Potato haulm was chemically desiccated with diquat dibromide 5–7 weeks before harvest of LP every year and 4 weeks before harvest of SP in 2009 only.

2.3. Sampling and analyses

Drainage water from each plot was measured during the main drainage period of the season in an underground station maintained at temperatures below 10 °C. Discharge rates were recorded with tipping buckets connected to a data logger, which measured accumulated daily drainage volumes from each plot.