NITROGEN RECYCLING IN POTATO ROTATIONS

by
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Introduction

The conservation of nitrogen (N) in irrigated crop rotations of the Columbia Basin will require an understanding of N cycling processes that occur during and outside of the cropping season. Hammond (1992) observed that inorganic soil N levels during corn cropping was elevated by early N fertilization and soil organic matter mineralization, then declined mid-season as the crop accumulated N at an accelerated rate, followed by a subsequent rise in inorganic N levels as N uptake efficiency declined during grain development. Soil nitrate continued to increase into the winter months as the crop senesced and crop residues and soil organic matter continued to mineralize. Thornton et al. (1997) have observed similar patterns of soil nitrate during a potato growing season. This buildup of late-season and post season inorganic N is attributable to (i) decreased uptake efficiency of late-season N applications and (ii) warm, moist soil conditions that promote mineralization of soil organic matter and senescing plant tissue. Earlier root studies suggested that Russet Burbank roots decline during tuber bulking (Pan et al., 1994), which might account for the decrease in N uptake efficiency and increase in soil N late in the potato growing season. Refinement of preplant and in-season nitrogen applications will help to minimize nitrate leaching below the root zone during the early to mid stages of these summer crop seasons, however, alternative cropping strategies will be required to retain and recycle nitrate that builds up late in the summer cropping season and into the winter months.

A primary benefit of cover crops is their ability to retain nitrogen in the system during the leaching-prone winter months, reducing leaching losses and groundwater contamination. As a result, fertilizer nitrogen can be conserved through use of cover crops. Nitrogen is taken up by the cover crop over the winter, stored in the crop biomass and released again in the spring when cover crops are plowed into the soil or chemically killed (Weinert et al., 1995). The residual soil nitrogen is otherwise lost to deep leaching in fallow fields.

Winter cover crops can be used in potato rotations to: (i) provide a ground cover for reducing wind erosion; (ii) serve as a catch crop for recovering deep-leached nutrients such as nitrate; (iii) improve soil quality; and iv) release natural pesticides for suppressing potato pests including weeds, nematodes, and diseases. Fertilizer management requirements for a succeeding potato crop will be altered by the incorporation of cover crop residues, which can mineralize or immobilize nutrients, and have an allelopathic effect on early season potato root growth.

This Presentation is part of the Proceedings of the 1997 Washington State Potato Conference and Trade Show.

The objectives of this research were (i) to relate patterns of development to temporal changes in soil nitrate, and (ii) evaluate Brassica cover crops for N recovery and recycling to a succeeding potato crop.

Methods

Root studies. Root-monitoring rhizotron boxes were installed on research plots established by R. Thornton, M. Hammond and S. Victory at Othello, WA in 1995 and 1996. The transparent-faced boxes were constructed with 0.196 in thick tempered plate glass mounted onto a wooden frame. The 24 in x 19.7 in x 3.54 in inner dimensions of the box were designed to allow a half profile view of an irrigated potato root system.

Rhizotron boxes were established on two soil types (Timmerman and Quincy) and in two hill shapes (narrow and broad hilled). The plots were fertilized with 100 lb N acre^{-1} as NH_4NO_3 and cultivated prior to planting. Transparent-faced boxes were buried in the soil perpendicular to the plant rows, with one side aligned with the plant row at the top of the hill, and the other side aligned with the center of the adjacent furrow. A potato (***Solanum tuberosum*** cv. 'Russet Burbank') tuber seed piece was planted adjacent to the glass 6 inches below the soil surface beneath the top of the hill. Each box was scanned at 2 to 4 week intervals throughout the growing season. A portable, color scanner (Logitech Scanman Color) created 24 bit RGB color images of the developing root systems at 200 dpi resolution. A wheeled-carriage and track system was built to consistently guide the scanner in the same positions in consecutive scans over time. A motorized retrieval system provided a method for steadily retrieving the scanner from bottom to top during image capture. The scanner was lowered into the box with a wheeled-carriage that rolled on a metal-rod track embedded in the back wall of the box. The scanner was remotely activated and retrieved. Each box required 5 vertical scans. Image files from each rhizotron box required approximately 50 MB of disk storage space on the 500 MB hard drive.

Cover crop studies. Cover crop experiments were conducted at the Irrigated Research and Extension Station at Prosser, WA to determine benefits and constraints of inserting fall seeded brassicas into irrigated rotations before potatoes. Three treatments, replicated 4 times, included bare fallow, white mustard (*B. hirta)* and rapeseed (*B. napus)* cover crops. Soil samples were taken to six feet prior to cover crop planting in early September, 1995. Mustard biomass was evaluated upon winterkill in October and rapeseed biomass was taken on March 23, 11 days prior to cover crop plowdown. Canopy cover was measured by line-point intersection and image analysis. For the image analysis, photographs were taken of a 1 x 2/3 m area, and scanned to create digital images, which were analyzed for % green cover. Six foot soil samples were also taken at that time. Cover crops were plowed into the soil on April 2, 1996. Potatoes were planted on April 9 and the plots were fertilized with 102 lb N/acre, as ammonium nitrate, at the time of planting. Soil samples were taken to 1 foot on May 16, to 2 feet on June 3, July 18 and August 8 and to 6 feet on June 26 and September 23. The twelve plots were halved in mid-June to vary fertilization rates. One set was fertilized at a rate of 158 lb N/acre 6 weeks after planting, while the second set was not fertilized again during the growing season.

Petiole samples were taken from the fourth petiole in both high and low fertilizer input plots on July 18, August 8 and August 20. Potato plant and tuber samples were taken from the high fertilizer plots on June 19, July 18 and August 20. Potato plant and tuber samples were taken from low fertilizer plots on July 18 and August 20. The petioles, shoots and tubers were LECO-analyzed for nitrogen content. The final soil samples, taken September 23, were taken from both high and low fertilizer plots for 6 foot comparisons of nitrogen movement. Potatoes were harvested from the plots on September 24 to evaluate yield and quality of the tubers.

Results and Discussion

Cover crops. The white mustard frost killed on October 25, and the canopy cover by early spring had diminished as the above ground biomass died and dessicated. Nevertheless, more cover was observed in these plots compared to the bare fallow control , but less than the winter survived rapeseed (Figure 1). At the time of spring incorporation of the rapeseed on March 23, 1996, the cover crops had reduced the amount of nitrate-N in the 2-4 ft zone (Figure 2), which accumulated in the above ground biomass (Table 1). The plant N from the rapeseed was mineralized soon after incorporation, resulting in elevated soil nitrate >150 lb N/A in the top foot of soil by potato tuber initiation, and into the accelerated phase of nitrate uptake (Figure 3), while the nitrate level in the second foot was initially lower prior to planting, but increased to comparable levels of the fallow control by 60 days. Winter cover crop recovery of 150 lb N/acre that would otherwise be leached below the root zone of the next crop represents a substantial potential savings.

As described below, roots of Russet Burbank senesce during late tuber bulking, which may relate to the late-season increase in soil nitrate levels observed in this study, as well as others (Thornton et al., 1997).

Root Development. Profile images were collected from 12 rhizotrons estabished at Quincy, WA in 1995 and 1996. Rooting patterns were studied in two soil types (Quincy vs. Timmerman) and two hill configurations (pointed vs. broad). The images were stitched together and printed. Preliminary root length analysis primary roots grew to 2 ft depths by 28 days after planting with lateral roots initiated on the primary axes to depths of 1 to 1.5 ft. Root elongation occurred rapidly between shoot emergence and tuber initiation, with root lengths maximizing at tuber initiation (Figures 4 and 5). As observed in previous years, extensive root proliferation was observed in the furrow region by that stage. Also consistent with previous years, roots declined during tuber bulking (Figs. 1 and 2). Root lengths tended to be sustained longer into tuber bulking under the broad hills compared to the narrow hills. By the end of the season in 1996, root lengths were greater in the Timmerman than in the Quincy. The timeframe of increasing nitrate concentrations in and below the root zone (see R. Thornton/S. Victory's report) was correlated to the timing of root decline in this study. This suggests that N uptake efficiency declines during root senescence as tuber development competes with roots for limited carbohydrate supply.

References

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Table 1. Cover crop biomass and N concentrations at Prosser, WA in 1995/6.

Crop	Shoot dry matter	Shoot N	Root dry matter	Root N
Rapeseed	4.92 T/A	4.2 %	0.85 T/A	1.6 %
White mustard	4.77 T/A	4.3 %	0.68 T/A	1.8 %

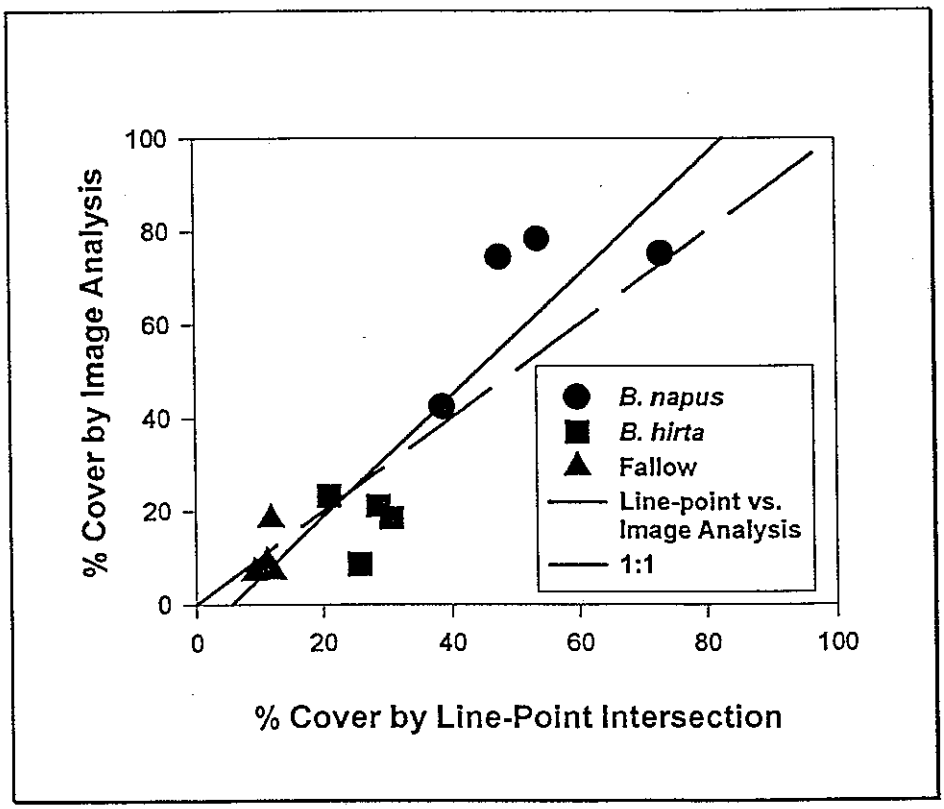

Fig. 1. Comparison of image analysis and line-point intersection methods for determining the area coverage of green canopy and crop residues from rapeseed, white mustard and fallow management on March 29, 1996.

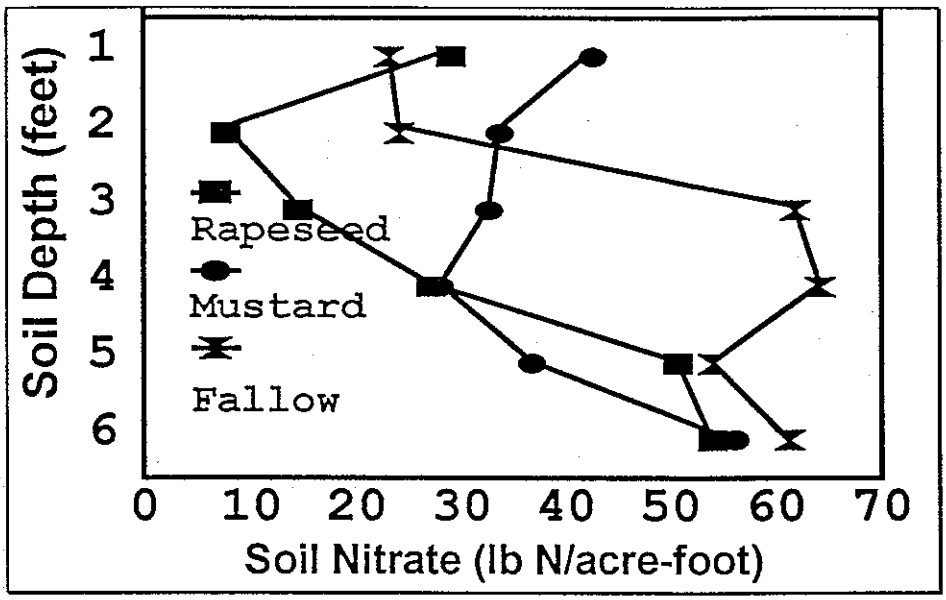

Fig. 2. Soil nitrate profiles at time of spring incorporation (March 23, 1996) as affected by rapeseed, white mustard or fallow.

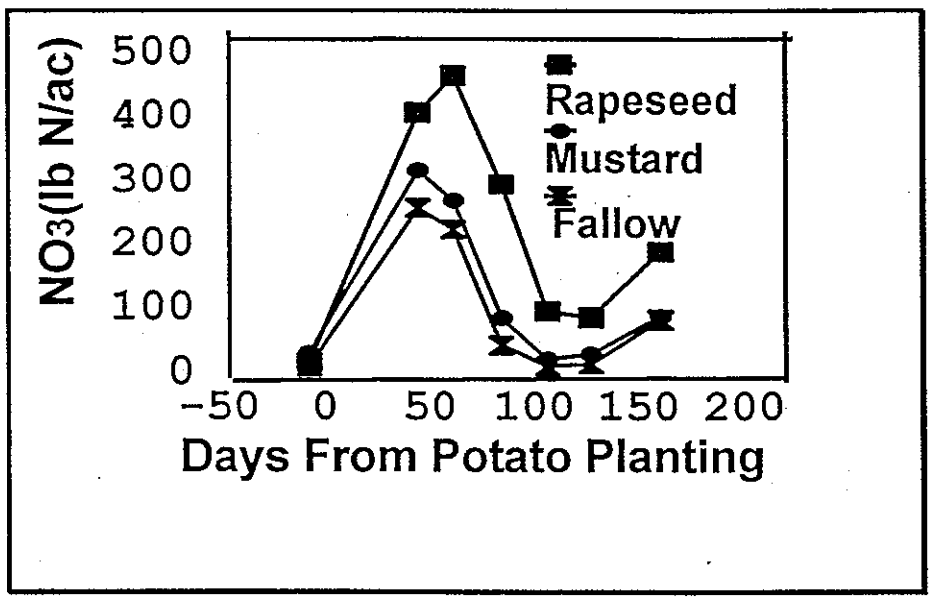

Fig. 3. Soil nitrate in the top 0-12" soil layer during the potato growing season (Prosser, 1996) as affected by cover crop N recycling.

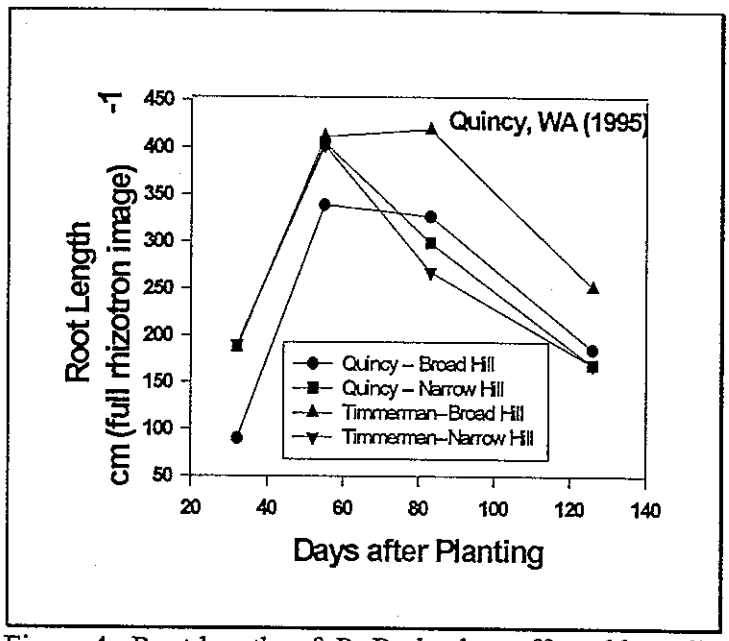

Figure 4. Root lengths of R. Burbank as affected by soil type and hill shape (1995).

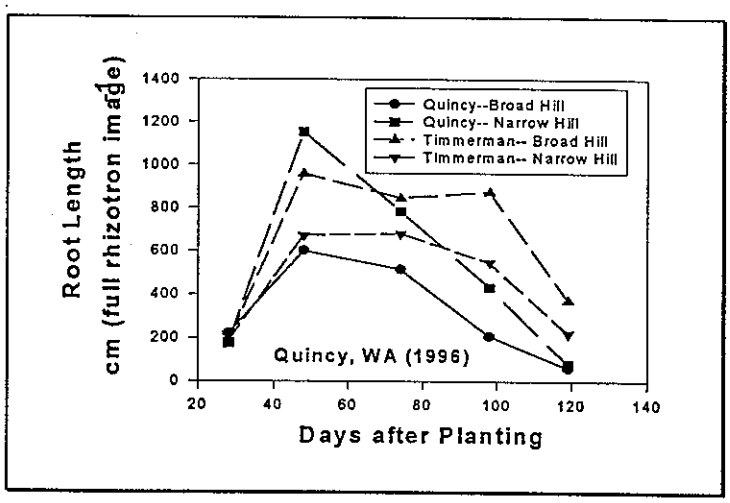

Figure 5. Root lengths of R. Burbank as affected by soil type and hill shape (1996)