Effects of irrigation and nitrogen management for potato tuber yield, N recovery and N leaching

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Abstract
As a controlled release N source, PSCU has the potential to increase total and marketable tuber yields with a single pre-plant application compared to urea source. However, there are still risks of leaching urea-N from a PSCU after the first few leaching events in sandy soils. Heavy early-season rainfall can deplete available soil N; thereby side-dress fertilizers might be still required to produce optimum tuber yields for both PSCU and urea treatments. Besides leaching, urea and urea-based controlled-release fertilizers can also result in volatilization and denitrification, resulting in lower N uptake as well as lower yields. Increase of N rate from 168 to 224 kg/ha barely benefits tuber yields, but increases the potential for leaching losses. Intermittent seepage irrigation can reduce water use and maintain or even increase tuber yield compared to the TSI if appropriate irrigation schedule is used. Nitrate leaching can also be minimized by supplying irrigation instead of over-nights over-days under ISI.

Key Words
Irrigation, nitrogen management, potato tuber yield, N recovery, N leaching.

Introduction
In northeast Florida, approximately 9,000 ha of potatoes are grown annually on coarse sandy soils in the St. Johns River watershed. The concern over increasing NO_3-N concentrations in the St. Johns River became a great challenge for competitive agricultural production, particularly potatoes, due to their high N requirement and low N recovery. Best Management Practices (BMPs) for potato production such as appropriate N rate with proper application time, optimum crop and irrigation management and control of N release are being developed by the University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS) to minimize N losses from agricultural fields. Use of controlled-release fertilizers (CRF) and slow-release fertilizers (SRF) may help reduce nitrate leaching and increase nutrient use efficiency. However, the CRF, especially sulfur-coated N sources, were also found to have certain negative effects on tuber yields (Lorenz *et al.* 1974; Elkashif *et al.* 1983), which is probably because of lack of synchronization between N release and potato demand (Waddell *et al.* 1999). By coating urea with a polymer, manufactures have greater flexibility in designing polymer-coated urea (PCU) with release rates that match uptake of specific crops and can produce similar or greater yields than soluble N fertilizers at equivalent rates (Zvomuya *et al.* 2003; Wilson *et al.* 2009).

The nutrient release from PSCU mostly depends on soil temperature rather than soil moisture or microbial activity (Paramasivam and Alva 1997). Nutrient release rate from PSCU was not determined in this study; however, referring to Paramasivam and Alva (1997), 80% of N from PSCU had been released after about 100 days. Seepage irrigation is a common practice for potato production in Florida. Under this type of irrigation system, a perched water table is maintained approximately 50 cm below the top of the row during irrigation events regardless of the physiological stage of the potato crop (Munoz *et al.* 2006). Seepage irrigation has low water use efficiency (20-30%) as compared with drip irrigation (85%) (Smajstrla *et al.* 2000).

The objective of this study was: 1) to determine the effect of PSCU at two N rates on potato tuber yields, N recovery by crops and N concentrations in the perched ground water; 2) to investigate the effect of intermittent seepage irrigation on potato yields and N concentration in the perched groundwater.

Materials and methods
This study was conducted during the 2006 to 2008 growing seasons on an Ellzey fine sand at the UF/IFAS Plant Science and Education Unit, Hastings Farm in Hastings, FL. The *traditional seepage irrigation* (TSI) which was commonly used by farmers in northeast Florida pumped water continuously through the crop season, except when a leaching rain event occurred. An alternate seepage irrigation method, *intermittent*

seepage irrigation (ISI), was also employed during this study for comparison, which supplied irrigation water 16, and 12 hours over the nights in 2006 and 2007, respectively, and 12 hours over the days in 2008. The experimental plots were arranged in a split-split-plot design. The whole plot factors were two irrigation treatments (TSI and ISI), the split plot factors were four N treatments which included a combination of two N sources (uncoated urea and polymer-coated sulfur-coated urea) and two N rates (168 and 224 kg N/ha), and the split-split plot factors were two potato cultivars (*Atlantic* and *Fabula*). Nitrogen treatments were arranged in a 2-way factorial design with four complete randomized blocks. All plots received 34 kg P_2O_5 and 197 kg K_2O/ha pre-planting.

Soil samples were taken prior to fertilizer application at the beginning of the season, at emergence, and at four-week intervals until harvest. The concentrations of NO_3-N and NH_4-N in soil samples were determined. Perched water was sampled from a 10-cm diameter PVC pipe buried in each subplot to a depth of 80 cm from the top of the center row. Water samples were collected biweekly starting the week of installation in 20-mL vials, frozen, and analyzed for NO_3-N and NH_4-N. Whole potato plants with tubers were collected at full flowering in all the study years. All ground tissue and tuber samples were analyzed for TKN. Potato tuber yields were determined by harvesting plants from 7.6 m row-length in the two center rows from each subplot and grading the tubers into five size categories based on tuber diameters according to USDA standards for grades of chipping potatoes (B=<4.8, A1=4.8-6.4, A2=6.4-8.3, A3=8.3-10.2, A4=>10.2 cm) (USDA, 1978). Category A1 to A3 were considered marketable yield. Total yield was calculated by the summation of all of the categories as well as culls (greens, cracked, misshapen, sunburn and rotten tubers). A sample of 20 tubers randomly selected from each subplot was determined for specific gravity using the weight-in-air/weight-in-water method.

Results and discussion

Rainfall and Irrigation

In 2006, only 13.8 cm of rainfall was recorded during the growing season, which is about 10 cm lower than the 10-year average (24 cm) for the same period. This rainfall was supplemented with 190 and 78 cm of irrigation by TSI and ISI, respectively. In 2007, total rainfall during the potato season was 23.4 cm, which is similar to the 10-year average. Traditional seepage supplied 192 cm of irrigation, compared to 96 cm by ISI. In 2008, total rainfall during the growth season was 19 cm, which was approximately 21% below the average. A leaching rainfall (8.7 cm in 3 days) occurred at 2 DAP, which was 7 days after fertilizing. The amounts of irrigation supplied by TSI and ISI were 187 and 107 cm, respectively.

Tuber Yield

In 2006, potato tuber yield was affected by irrigation methods. The TSI produced higher marketable yield (28.5 Mg/ha) compared to the ISI (22.1 Mg/ha). Neither N source nor N rate had an effect on the tuber yield. In 2007, the only difference in total and marketable yield detected was between the two potato cultivars. Neither irrigation nor N treatments had an influence on the tuber yield. In 2008, potatoes did not emerge 100% due to the heavy rainfall right after planting. Reduction of both total and marketable yield was recorded in this year. Leaching rainfall in the early season and poor tuber set could be responsible for the lower yields compared to the yields in the other two years. Compared to urea treatment, the PSCU with a single application pre-planting significantly increased total yield from 20.03 to 24.85 Mg/ha, and marketable yield from 14.98 to 17.90 Mg/ha. Compared to the TSI, the ISI increased marketable tuber yields from 16.2 to 20.2 Mg/ha. As a controlled-release N source, PSCU resulted in different tuber yields in the three production years comparing with uncoated urea. The most probable reason might be that a significant leaching rainfall occurred 7 days after fertilization, which might have resulted in significant leaching loss from uncoated urea than from PSCU. Wang and Alva (1996) found that in sandy soils, leaching of N from a soluble N source may depend on the first few leaching events. Hutchinson *et al*. (2003) found no difference of total and marketable yield by using a combination of 50% of PSU and 50% of PSCU compared to using a combination of 50% of ammonium nitrate (AN) and 50% of urea at the N rate of either 168 or 224 kg N/ha. In 2006, the average rainfall during the growing season was 42% lower than the 10-year average. Intermittent seepage supplied only 41% of irrigation water compared to traditional irrigation. In 2007, intermittent seepage supplied more irrigation water than that in 2006. Combined with more rainfall during the growing season, intermittent seepage produced similar tuber yield to TSI. In 2008, irrigation supplied by the ISI was increased to 57% of that of TSI, which could be a reason why ISI produced more tuber yield than TSI. Besides, irrigation schedule was changed from over-nights to over-days, resulting in stable water table maintenance and an increased yield in 2008.

NO_3-N concentration in the perched groundwater

Nitrogen sources did not affect the average NO_3-N concentrations in the perched groundwater in any year. This may be due to a high dilution of nutrients in the large perched water table below the plots. Pack *et al.* (2006) found also found that no significant difference in NO_3-N concentration was found between treatments in perched water table samples. Wang and Alva (1996) suggested that in sandy soils, leaching of urea-N can be an important part of total N loss from urea-based slow-release fertilizers, especially with the first precipitation events. The lower N leaching from urea might be the result of loss N through volatilization and denitrification. Bundy *et al*. (1986) suggested that urea-N could be lost by leaching of unhydrolyzed urea, volatilization and greater loss through leaching due to more rapid nitrification compared to ammonium N source. Zvomuya *et al*. (2003) found that a single application of PCU improved recovery of N and reduced NO_3 leaching compared with three application of urea. Similar results were reported by Waddell *et al*. (2000), comparing SCU with urea treatment. Due to different irrigation schedules, seepage irrigation treatments had different effects on nitrate concentrations in the perched groundwater. In 2006 and 2007, significant higher nitrate concentrations under ISI were found compared to that under TSI. However, in 2008, nitrate concentration under ISI was similar to that under TSI. This different result suggested that supplying irrigation over-days reduced water table fluctuations, reducing nitrate leaching under ISI.

Nitrogen recovery

Similar to the yields, *Fabula* cultivar accumulated more N in vines and tubers compared to *Atlantic*. In 2008, PSCU was found to have an advantage in N recovery by tubers. Vine and total N uptake was increased with N rate. N content in *Fabula* tubers was higher than in *Atlantic*, which induced to a higher total N uptake by *Fabula*, no difference, however, was detected in the two cultivars' vines. Similarly, N recovery by potato crops was quite different in 2007 and 2008. An average of 130.6 kg N/ha was up taken by potato crops in 2007, which exceeded an average of 76.6 kg N/ha uptake in 2008. All the N recovery results agreed with the effect of N and cultivar treatment on total and marketable tuber yield. Nitrogen content in potato roots was not measured in this study. It is likely that there were some differences of N content in the roots for various N treatments. The difference between two years might result from more leaching losses of N in 2008. Hutchinson *et al*. (2003) also reported on differences of N uptake by plants by using PSCU and urea.

Conclusions

As a controlled release N source, PSCU has the potential to increase total and marketable tuber yields with a single pre-plant application compared to urea source. However, there are still risks of leaching urea-N from a PSCU after the first few leaching events in sandy soils. Heavy early-season rainfall can deplete available soil N; thereby side-dress fertilizers might be still required to produce optimum tuber yields for both PSCU and urea treatments. Besides leaching, urea and urea-based controlled-release fertilizers can also result in volatilization and denitrification, resulting in lower N uptake as well as lower yields. Increase of N rate from 168 to 224 kg/ha barely benefits tuber yields, but increases the potential for leaching losses. Intermittent seepage irrigation can reduce water use and maintain or even increase tuber yield compared to the TSI if appropriate irrigation schedule is used. Nitrate leaching can also be minimized by supplying irrigation instead of over-nights over-days under ISI.

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