POLYMER COATED UREA IN POTATO PRODUCTION

Trent W. Taysom, Bryan G. Hopkins, Amanda K. Shiffler and S. Chod Stephens
University of Idaho, Aberdeen Research and Extension Center
Aberdeen, ID

ABSTRACT

Nitrogen (N) is the most important mineral nutrient in potato (Solanum tuberosum) production. Studies show a steady, but not excessive, supply of N is important for maximum tuber yield, size, and solids, as well as minimal internal and external defects. Although more costly and labor intensive dry broadcast applications, growers typically apply the majority of N through the irrigation water in-season in order to maximize yield components. A controlled release N fertilizer, in the form of polymer-coated urea (PCU), is a possible alternative to the grower's standard practices. A newly formulated PCU may meet plant demand more timely and efficiently through temperature-controlled release of N into the soil solution. This improved efficiency could increase yield and tuber quality, prevent excess N loss from leaching and denitrification, and allow a more convenient and less labor-intensive fertilization system. The objectives of this study are to determine the effects of PCU on the yield and quality of Russet Burbank potatoes grown in Southeast Idaho. Nitrogen was applied at four rates (33, 67, 100, or 133% of recommended) with four methods of application, namely: 1) urea at emergence, 2) PCU at emergence, 3) split urea with half applied at emergence and the remaining applied in three in-season applications, and 4) PCU at pre-plant. The PCU pre-plant treatment was only applied at the 67% rate. Results showed increases in US No. 1, marketable, and total yield, as well as increases in crop value for PCU treatments (especially the 67% rate) over the other treatments.

INTRODUCTION

Potatoes (*Solanum tuberosum*) are of major economic importance in the irrigated Western U.S. A large portion of the most productive, intensively cultivated regions in these states (e.g. Snake River Plain, Columbia Basin, San Luis Valley, San Joaquin Valley, etc.) are dominated by potato cropping systems. From a national perspective, only grain, bean, and cotton crops exceed potatoes in terms of row crop production value and acreage. With production costs commonly between \$1400 and \$2200 per acre, potato growers are relatively more willing to properly fertilize and care for this high value crop to ensure maximum yields and quality tubers.

One of the foremost management priorities in potato cropping systems is nitrogen (N) (Stark et al., 2004). Typically, nitrogen is the most limiting nutrient in crop production and is found in higher concentrations than all other mineral nutrients in plants (Ludwick et al., 2002). Potatoes are especially sensitive to N nutrition.

Potatoes require a modest amount of N during the early part of the season for adequate canopy development. However, excessive N at this time results in the delay of tuber initiation (tuberization) by 7 to 14 days, resulting in reduced tuber yields. Once tubers are formed and begin the bulking phase, the potato plants require an adequate, steady supply of N. Deficiencies of N reduce canopy growth and often result in premature senescence, resulting in reduced yields. Excess N during this portion of the season results in slowed tuber bulking in favor of vegetative growth. Widely fluctuating N levels result in irregular tuber growth and often end in the formation of internal (brown center and hollow heart) and external (misshapen) tuber deformities. As maturity approaches, the N level in the plant must subside in order to maximize relocation of above ground carbohydrates into tubers and enhance the formation of an adequate outer layer of "skin" on the tubers.

Based on these facts, potato growers commonly "spoon feed" N throughout the growing season. They will apply 25-50% of the recommended N pre-plant or at plant emergence when cultivation occurs. The remainder is applied by injection into the irrigation water and is based upon need, as determined by weekly petiole nitrate-N analysis. Although this practice helps to increase yields and improve tuber quality, it is labor intensive and the liquid N fertilizer sources used in the injection process are more costly than the dry forms applied prior to emergence.

Another benefit of split applications is improved N use efficiency (NUE). Rising natural gas prices have resulted in significant increases in N fertilizer prices and, in turn, the need for improved fertilizer efficiency is increasingly important. The risk of N loss is proportional to the time it resides unused in the soil and, therefore, it is beneficial to apply or convert N as close to the time of plant need as possible. Nitrate-N is subject to loss from the plant root zone through leaching (especially in sandy soils), denitrification (especially in clay soils), and runoff/erosion (especially on landscapes significant slopes and compacted/crusted soils). Ammonium-N is also subject to runoff/erosion, as well as to volatilization in alkaline soils common in potato growing regions. New fertilizer material/methods are needed to reduce N loss and to curb input costs.

Controlled Release Nitrogen (CRN) sources are a class of N fertilizers that may eliminate or reduce labor intensive and costly in-season N applications, as well as increase NUE. CRN releases N at controlled rates to maintain maximum growth and minimize N loss. The two main forms of CRN are compounds of low solubility and coated water-soluble fertilizers (Blaylock et al., 2005). Previous work with CRN has been mostly unsuccessful in potatoes as the N release was too early and unpredictable, resulting in delays in tuberization and yield loss.

Polymer-Coated Urea (PCU) fertilizers are one type of CRN that have the potential to provide improved N release timing. One such PCU is Environmentally Smart Nitrogen (ESN, Agrium U.S. Inc., Denver, CO). ESN was designed to release N to the crop with more control and predictability with a micro-thin polymer coating. The N release rate is controlled by soil temperature, which coincides with plant growth and nutrient demand. The process of release is called temperature-controlled diffusion. In this process, water moves into the fertilizer granule through the coating and dissolves the N into solution. As temperature increases, N moves out through the polymer coating into the soil solution (Agrium, 2005).

Applying ESN fertilizer at planting or at cultivation may better meet the potato crop's nutritional needs for a steady supply of N for superior yields and tuber quality, reduce in-season labor/management efforts, and potentially improve net crop value.

OBJECTIVES

Compare four rates of fertilizer N applied as ESN at emergence to urea applied at the same time and urea split applied (grower's standard practice) with regard to potato tuber yield, size, grade, solids, and internal/external defects. Also, compare ESN applied at emergence at a 67% of recommended rate with ESN applied pre-plant at the same rate for the same yield parameters.

METHODS

Three field experiments evaluating the effectiveness of ESN on *Russet Burbank* potatoes were conducted in fields in southeast Idaho near Blackfoot (Bannock loam), Aberdeen (Declo loam), and Rupert (Sluka silt loam) in 2006. A total of 14 treatments were evaluated: an untreated check, four rates of N (90, 180, 270, and 360 lb-N/a) applied as either ESN (44-0-0) or urea (46-0-0) at cultivation, four rates of urea (90, 180, 270, and 360 lb-N/a) split applied and a pre-plant ESN treatment (180 lb-N/a). The N rates used represent 33%, 67%, 100%, and 133% of the University of Idaho fertilizer recommendations based on soil test values and previous crop information. The pre-plant ESN treatment was included to address the question of timing of application. Research conducted at the University of Minnesota (Carl Rosen, personal communication 2005) found that ESN applied before planting may release N too early for crop need and result in a substantial delay in tuber initiation and, thus, yield losses.

The treatments applied at cultivation occurred near the time of emergence and were cultivated into the soil 1-2 days after application. Cultivation treatments were applied on June 3rd for Aberdeen (28 DAP) and Blackfoot (16 DAP), and May 18th Rupert (16 DAP). The pre-plant ESN treatments were applied 1-2 days prior to planting on May 5th, 16th, and 1st for Aberdeen, Blackfoot, and Rupert, respectively, with incorporation accomplished through the planting/hilling process. All N applications were made using a rotary hand spreader to apply pre-weighed fertilizer uniformly across the plot area.

The split applied treatments had 50% of the N applied at cultivation; with the remaining applied in three equal increments throughout the growing season. Timing of the first in-season application was based off of petiole nitrate analysis of composite samples from the 100% split application method and University of Idaho in-season N recommendations (Stark et al., 2004). The first in-season application took place on July 15th for Aberdeen and Blackfoot and on July 13th for Rupert, respectively. The following two in-season applications were applied every two weeks thereafter.

Plots were 12 feet wide (four 36 inch rows) by 40 feet in length. The experiment was set up as a randomized complete block design (RCBD) with 4 replications at each location. Standard grower practices were followed to ensure N was the only limiting factor. However, irrigation and herbicide residue problems caused a severe tuber quality problem at the Rupert location. The Blackfoot location also had production problems, but was due to a severe early die (*Verticillium* wilt) infection that resulted in canopy senescence 2-3 weeks earlier than desired. Approximate rainfall (inches) from the first of May to the 13^{th} of September was 2.97, 1.61, and 1.84 for Aberdeen, Blackfoot, and Rupert, respectively; with no single precipitation or irrigation event so great in magnitude that it resulted in leaching or denitrification losses of nitrate-N.

Vines were killed on September 11and 13th for Aberdeen and Rupert, respectively. Vines were not killed at Blackfoot because they were 90% senesced on the date of scheduled vine kill. Harvest occurred on October 6th, October 13th, and September 18th for Aberdeen, Blackfoot, and Rupert, respectively. Twenty row feet were harvested from each of the center two rows of each plot. Tubers were stored in burlap bags for 21 to 31 days until they could be graded for size, shape, internal/external defects, and specific gravity based on USDA potato grading standards. After grading and weighing, a random sub sample of two tubers was taken from each of the four US No. 1 size categories (4-6, 6-10, 10-14, and >14 ounces). These eight tubers were used to evaluate specific gravity (solids) and internal quality (primarily the occurrence of hollow heart and brown center).

Two plots at the Rupert location were lost due to irrigation malfunction and, therefore, the data was analyzed by GLM (General Linear Model) with a P=0.10 criteria. Means were separated by Duncan's Multiple Range test with an alpha of 0.05.

RESULTS AND DISCUSSION

Differences for individual grades, sizes, specific gravity, and tuber defects of the potatoes were generally significant, but the primary response was seen when comparing fertilized versus unfertilized plots. No clear trends were apparent when comparing ESN with either method of applying urea. However, when combining sizes and/or grades, significant differences become apparent.

Most potato growers are paid based, at least in part, on total yield. Differences by treatment for total yield were highly significant (Fig. 1), with only the 33, 67, and 100% rates of ESN and the 67% split having significant increases over the unfertilized check. It is important to note however, that the location interaction was highly significant, thus, requiring investigation of the response at each location. The Rupert location had severe problems with both herbicide carryover and soil moisture, resulting in yield loss and no response in total yield to N fertilization. The Blackfoot location also had reduced yields, but in this case, the loss was due to severe early die complex. All fertilized plots at the Blackfoot location had higher yields than the untreated check, but the response was not significant across individual treatments. In contrast, the Aberdeen location had high yields with a significant response for the 67 & 100% ESN treatments performing better in total yield than all other treatments except 133% ESN.

Although total yield is important, premiums are often paid (especially for fresh market growers) for tubers that have good symmetry and are free of defects and abnormalities (US No. 1 grade). Although only significant at the P=0.10 level, the US No. 1 yields for this trial showed similar trends as the total yields (Fig. 1). All of the ESN treatments were significantly better in US No. 1 yields than the untreated check. The only urea treatments better than the untreated check were the 100 and 133% split treatments. In addition, only the 67% ESN treatment had significantly more US No. 1 yield than all of the non-split urea treatments. Unlike total yield, the location interaction was not significant for US No. 1 yields, with apparent increases in US No. 1 yields at all three locations at similar magnitudes.

Growers with processing contracts, primarily for the fried potato products industry, are often paid incentives for "marketable" tubers. Marketable includes the combination of US No. 1 and US No. 2 tubers. Although only significant at the P=0.10 level, the marketable yields for this trial showed similar trends as the total yields and a nearly identical response to the US No. 1 yields (Fig. 1). All of the ESN treatments applied at emergence (not the pre-plant ESN) were significantly better in marketable yield than the untreated check. The only urea treatments better than the untreated check were the 33 and 133% split treatments. And, similar to the US No. 1 yield results, only the 67% ESN treatment had significantly more US No. 1 yield than the 33 and 67% non-split urea treatments. As with total yield, the location interaction was significant for marketable yield. Most of the fertilized treatments had numerically lower marketable yield than the unfertilized check for the Rupert location, whereas all of the fertilized treatments had higher marketable yield than the unfertilized check at the Blackfoot and Aberdeen locations. However, only Aberdeen had marketable yield statistical significance when locations were individually analyzed.

Applying contract pricing and fertilizer costs is highly speculative, but an estimate is shown in Fig. 2 for five year average grower contracts and current season fertilizer prices (assuming

ESN at 20% higher cost than uncoated urea). Differences in gross crop value, with or without incentives were highly significant, with all of the ESN treatments significantly better in gross crop value and gross crop value plus incentives than the untreated check. The only urea treatments with increased crop value compared to the untreated check were the 67 and 133% split treatments for gross value and 133% for value plus incentives. Only the 67% ESN treatment had significantly more gross crop value, with or without incentives, than all of the non-split urea treatments. The 67% ESN treatment also had significantly more gross crop value plus incentives than all of the split applied urea except the highest rate. When the cost of the fertilizer was subtracted from the gross crop value plus incentives, only the 33 and 67% ESN applied at cultivation and the 67% ESN applied pre-plant had significantly better net crop value than the untreated check.

The location interaction was highly significant for gross crop value, with and without incentives, but not for net crop value. An examination of gross crop value at each location showed similar trends as reported above for US No. 1 yields for all three locations, with only Aberdeen and Rupert locations being statistically significant.

When combining across rates, both ESN and urea performed significantly better than the untreated check for US No. 1, marketable, and total yield; as well as for gross crop value and incentive adjusted value. However, only ESN ($1,084.63) was significantly better than the untreated check ($936.50) in net value when factoring in all crop value parameters and fertilizer cost estimates, whereas urea ($1,012.19) was not.

In summary, ESN performed as well as or better than the other N fertilization treatments evaluated in this study. This data agrees with data from a single location in the previous year, as well as data from similar studies in 2005 and 2006 in Minnesota (Carl Rosen, University of Minnesota, personal communication 2006). This is significant in that it presents a possible mechanism by which growers can meet their potato crop's N needs with improved efficiency and profitability with less environmental risk and labor.

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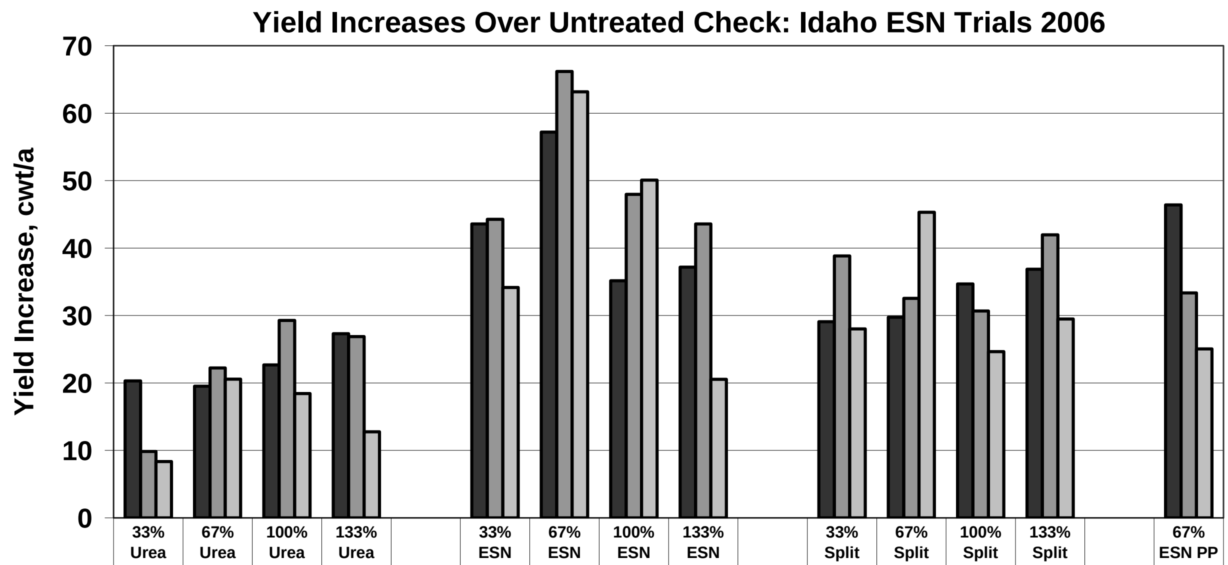
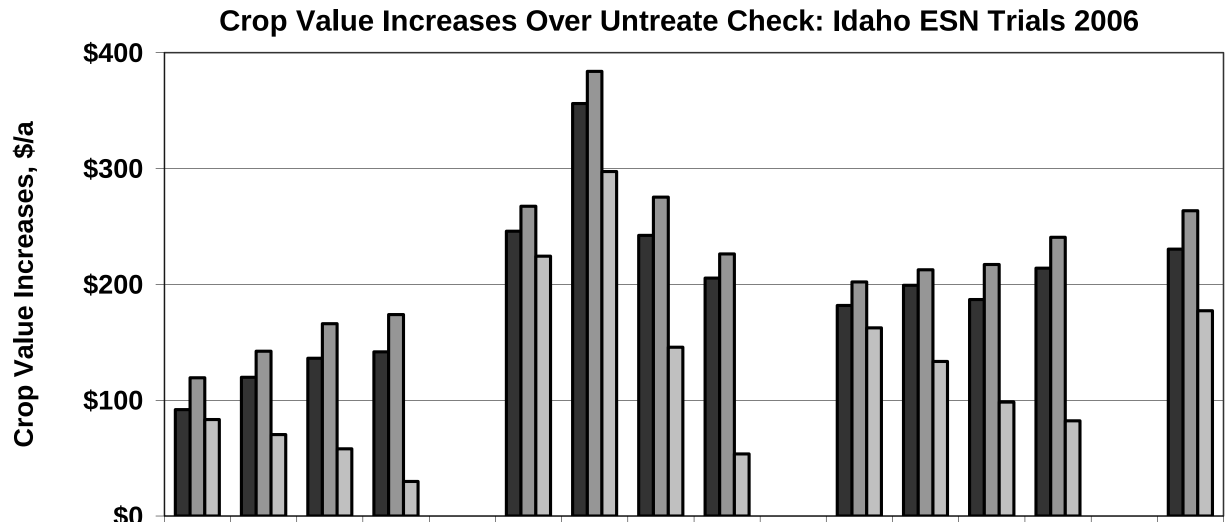


	33% Urea	67% Urea	100% Urea	133% Urea		33% ESN	67% ESN	100% ESN	133% ESN		33% Split	67% Split	100% Split	133% Split		67% ESN PP
US1	20	20	23	27		44	57	35	37		29	30	35	37		46
Marketable	10	22	29	27		44	66	48	44		39	33	31	42		33
Total	8	21	18	13		34	63	50	21		28	45	25	29		25

Fig. 1. Combined potato tuber yield increases over an untreated check for three Idaho ESN field trials near Aberdeen, Blackfoot, and Rupert in 2006. Nitrogen was applied at four rates with 33, 67, 100, or 133% of recommended. Four methods of application were used, namely: 1) urea at emergence, 2) ESN at emergence, 3) split urea with half applied at emergence and the remaining applied in three in-season applications, and 4) ESN at pre-plant (PP). The ESN PP treatment was only applied at the 67% rate and was included for comparison purposes only. Three yield categories are reported, namely: US No. 1, Marketable (US No. 1 and 2 combined), and total (marketable plus culls). Differences for total yield were highly significant (LSD 31 cwt/a) and differences for US No. 1 (LSD 33 cwt/a) and Marketable (39 cwt/a) were slightly significant at *P*=0.10.



	33% Urea	67% Urea	100% Urea	133% Urea		33% ESN	67% ESN	100% ESN	133% ESN		33% Split	67% Split	100% Split	133% Split		67% ESN PP
Gross Value	92	120	136	142		246	356	242	205		182	199	187	214		230
Gross + Incentive	119	142	166	174		267	384	275	226		202	213	217	241		264
Net Value	83	70	58	30		224	297	146	54		162	134	98	82		177

Fig. 2. Combined potato crop value increases over an untreated check for three Idaho ESN field trials near Aberdeen, Blackfoot, and Rupert in 2006. Nitrogen was applied at four rates with 33, 67, 100, or 133% of recommended. Four methods of application were used, namely: 1) urea at emergence, 2) ESN at emergence, 3) split urea with half applied at emergence and the remaining applied in three in-season applications, and 4) ESN at pre-plant (PP). The ESN PP treatment was only applied at the 67% rate and was included for comparison purposes only. Three crop value categories are reported, namely: Gross, Gross plus Incentives, and Net. Incentives include premiums for high US No. 1 and tuber size percentages, high specific gravity (solids), and low incidence of internal defects (hollow heart and brown center). Net value equals gross plus incentives minus fertilizer costs. Differences for gross crop value, without (LSD $160/a) or with (LSD $169/a) incentives were highly significant and differences for net crop value (LSD $175/a) were slightly significant at *P*=0.10.