PETIOLE NITRATE TRENDS ACROSS EIGHT POTATO CULTIVARS:

FINAL REPORT

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INTRODUCTION

Escalating fertilizer prices and water quality concerns (nutrient leaching) are forcing growers to improve their fertilizer use efficiency. Moreover, cultural management needs of many new cultivars have yet to be defined. Recent research and grower experience with new releases like Alturas and Premier Russet (A93157-6LS) have demonstrated that reducing in-season nitrogen below what is commonly applied on Russet Burbank (RB) may actually provide a higher economic yield for some cultivars.

Growers are more likely to utilize recommendations coming from research that closely mimics operations similar to theirs. For in-season fertilizer application, most Washington potato growers deliver nutrients to plants via their irrigation systems. This method is commonly referred to as fertigation or chemigation. Beyond the issues of year to year crop growth variations and regional differences, the largest difficulty in developing in-season potato fertility recommendations has been the inability to conduct research trials with a large number of fertilizer treatments while utilizing irrigation water as the treatment carrier. The objectives of this research trial were 1) to develop a reliable research method that closely mimics fertigation and allows for a large number of treatments, 2) identify new and existing cultivars that produce economically superior yields with an in-season level of nitrogen that is reduced below current recommendations for RB, 3) determine if petiole nitrate values from several new and existing cultivars respond similar to RB, and 4) utilize cues and application method from this preliminary trial to design future trials in an effort to fine-tune the fertility requirements for commonly grown cultivars.

MATERIALS AND METHODS

Three field experiments in the Columbia Basin of Washington were conducted during 2005-07 to compare the effects of two in-season N rates on eight potato cultivars. The potato cultivars included: ‘Russet Burbank’ (RB), ‘Ranger Russet’, ‘Umatilla Russet’, ‘Alturas’, ‘Defender’, ‘GemStar’, ‘Premier Russet’ (A93157-6LS), and ‘A95109-1’. The two in-season N rates were: 1) 100% of typical RB in-season needs and 2) 50% of typical. A soil test was used to determine pre-plant fertilizer needs across the trial sites. One rate of pre-plant N and adequate quantities of P, K, S, Boron, and Zinc, were broadcast across the trial areas each year prior to planting.

Available N for each treatment during 2005, 2006, and 2007 was (pre-plant + in-season + soil residual): 100% = 348-, 368- and 356-lbs N/A, respectively, and 50% = 232-, 262- and 251-lbs N/A, respectively. In-season N was applied with 0.15 in/A of water weekly during June and July. The 100% and 50% treatments received an average of 220- and 120-lbs/A in-season, respectively.

Nutrient applications for the 100% treatment were based on recommendations in the 1999 Washington State University Extension Bulletin No. 1871 “Potato Nutrient Management for Central Washington” and from the recommendations of several local consultants. Between 10 days after > 90% emergence (DAE) and up to 93 DAE, 10 petioles were collected weekly from each plot to determine nutrient needs for each cultivar. Nitrogen was applied one to two times weekly during the same time period and rates were adjusted according to the petiole and soil N concentrations (Figure 1). A pull-type sprayer (fertigation simulator) outfitted with a 500 gal tank and flood-nozzles was calibrated to deliver urea ammonium nitrate solution 32-0-0 (UAN 32) in 0.15 in/A water on each plot. The in-season application rates were adjusted in an attempt to keep the 100% treated RB's petiole nitrate concentration between 20,000 - 25,000 and soil N above 50lbs/A until approximately 40 DAE. Beyond 40 DAE, the petiole and soil N concentrations were allowed to slowly decline.

Each experiment was arranged in a randomized complete block design with four replications. Certified seed tubers were hand-cut into pieces between 43 and 85 g and planted using a custom-built assist feed planter. Planting depth from the top of the seed piece to the top of the hill was 8 inches and in-row seed piece spacing was 10 inches. Furrows were ripped 16 inches deep at approximately 30 days after planting (DAP) using a dammer-diker implement with no change to final seed-piece depth. Row width was 34 inches with plots 4 rows by 15 feet. The center two rows were used to collect petioles and data. To apply competition to the end plants, each plot end was guarded with the potato cultivar, 'All Blue'. All experiments were planted near Othello, Washington in a Shano silt loam soil and grown with overhead sprinkler irrigation under regional-standard practices for RB. Planting dates were April 6, 2005, April 11, 2006, and April 16, 2007.

Final plant emergence counts and aboveground stem numbers were recorded at 50 DAP. To calculate the harvest index ((tuber wt/aboveground fresh wt + tuber wt) x 100) for each treatment and cultivar, four intact plants from one center row of each plot were harvested at 83-, 86-, and 92-DAE during 2005, 2006, and 2007, respectively. To avoid any potential plot-end effects, the plant nearest the end was discarded and the remaining three plants were used to collect the data.

Vines were removed with a flail 5 to7 days prior to the final harvest. Both center rows of each plot were harvested using a one-row mechanical harvester on 174-, 163-, and 175-DAP in 2005, 2006, and 2007, respectively. Each harvested tuber was washed, weighed and counted. Total tuber yield was partitioned into U.S. No. 1, U.S. No. 2, malformed, and green categories. Five 340 to 397 gram tubers from each plot were evaluated for hollow heart, internal brown spot, and brown center defects. Length and width of five 227 to 397 g tubers from each plot was measured and the length to width ratio was calculated. A composite of 20 tubers weighing between 227 to 397 g was used for weight-in-water/weight-in-air specific gravity determination.

Fresh and process gross income minus the fertilizer expense for each treatment and cultivar was determined. Fresh market gross income was determined using four-year regional-average fresh-market values for 1999/00 to 2003/04 market periods (USDA Federal-State Market News Service 2000-2004). A mock processing contract was used to determine gross process market income and was based on actual regional values.

During the gross income calculations, the nitrogen expense was calculated using a value of $0.80/lb of N. All data were analyzed using analysis of variance and the means statistically separated using Fisher's Protected Least Significant Difference Test at the 0.05 level of probability.

RESULTS

Emergence dates across all three years were quite similar. More than 90% of plants from most cultivars emerged by May 19, May 22, and May 21 during 2005, 2006, and 2007, respectively.

Because N applications were based on previous petiole analyses, the application timing and rate varied each year (Figure 1). As expected, petiole NO3-N concentration and available soil N declined as the season progressed. Moreover, actual petiole concentration values for RB (Figure 1) and the other cultivars (data not shown) varied by year due to the natural variation in growing conditions; however, the separation between the 100% and 50% treatments was distinct and typically increased as the season progressed (Figures 1 & 2). Based on the significant differences between the rates across all cultivars and years, the fertigation simulator appears to be a reliable method for conducting in-season nutrient research that mimics commercial fertigation.

Correlation analyses revealed that petiole NO3-N concentrations of most cultivars tracked closely with RB over time (Figure 3). Across all years, A95109-1, Premier, Alturas, and Umatilla petiole values were more similar to RB than Ranger, Defender, and GemStar. The petiole values of Defender and Ranger were least like RB and were typically higher across each season (Figure 4). In fact, all cultivars had higher average petiole concentrations than RB over the course of the study (Figure 4). Petiole concentrations of Umatilla and Premier were only slightly higher than RB and the higher values were typically were typically seen prior to 80 DAP.

Plants with less in-season N had a higher harvest index than those with more in-season N when averaged across all cultivars (Table 1). This indicated that the plants with less N focused their energy on tuber production at the expense of vine production. Plants that received the lower rate of N typically responded with earlier and more severe vine senescence toward the end of the season (Table 1).

Averaged across all cultivars, total, processing and US No. 1 yields suffered when less in-season N was applied (Table 2 & 3). Umatilla was the only cultivar that had a significant reduction of these yields when analyzed separately from the other cultivars. It is possible that if this study was conducted an additional year or two that several other cultivars would respond with significantly lower yields.

A95109-1 produced proportionately more carton-grade tubers when grown with less in-season N, but no response was seen from the other cultivars (Table 2). Specific gravity was higher and shatter bruise slightly reduced when less in-season N was applied (Table 3). RB also had less brown center, and A95109-1 less IBS with reduced N (Table 3).

With the exception of Umatilla, gross returns were not affected by in-season N rate (Table 1). Only Umatilla produced higher gross returns when grown with the 100% in-season N treatment. Other than for Umatilla, higher yields that resulted from the higher in-season N rate were offset by the cost of the additional N that was applied.

These findings further strengthen the argument that maximum total yield and maximum economic yield are not always equal. For some cultivars, there appears to be a range at which in-season N can be applied to maximize profits.

DISCUSSION

These findings indicate that maximizing total yield does not always maximize economic value. In addition, there appears to be a range at which in-season N can be applied to maximize profits, except maybe for Umatilla.

Yields typically suffered with the reduced rate of N, but the ECONOMIC yield was not significantly different for seven cultivars after accounting for the N expense.

Reduced N increased the harvest index, tuber dry matter (specific gravity), and reduced internal defects. Moreover, lower N rates likely reduced the chances of ground water contamination from leached nitrates.

It is possible that the key to success with the reduced in-season N is that the plants get adequate pre-plant or up-front N. After sufficient pre-plant N (approx. 125-150 lbs, soil residual + applied), growers may have economic success by reducing the in-season water-run N below what is typical for RB. However, growers should use caution when diverting from their standard practices. For major changes in production, such as altering in-season nutrients or trying new cultivars, we recommend growers experiment on a small field or half of a pivot, with some way of comparing their new practices or cultivar to the reliable standard.

Where certain diseases afflict cultivars like RB, higher doses of in-season N may keep plants alive longer and provide more vigorous vines. With Alturas, A93157-6LS, and A95109-1 a reduced rate may be best; A93157-6LS tend to have less hollow heart, A95109-1 tubers are a more marketable size, and Alturas appears to do fine with reduced N. As fertilizer prices increase, lower in-season nutrient rates may become even more desirable. Growers are encouraged to remember that maximum biological yield is typically not the same as maximum economic yield. Moreover, the maximum economic yield shifts as the cost of inputs rises.

The nutrient requirements for these eight cultivars needs to be better defined, especially for the newest releases. Because this new application method appears to work well, more detailed research will be conducted on each cultivar in the near future. This research will be updated and reported during future Washington State Potato Conferences and local meetings following future research efforts. Because it is likely the recommendations for each cultivar will become more specific in the future, growers should contact their local extension personnel or the authors of this paper for the latest nutrient recommendations.

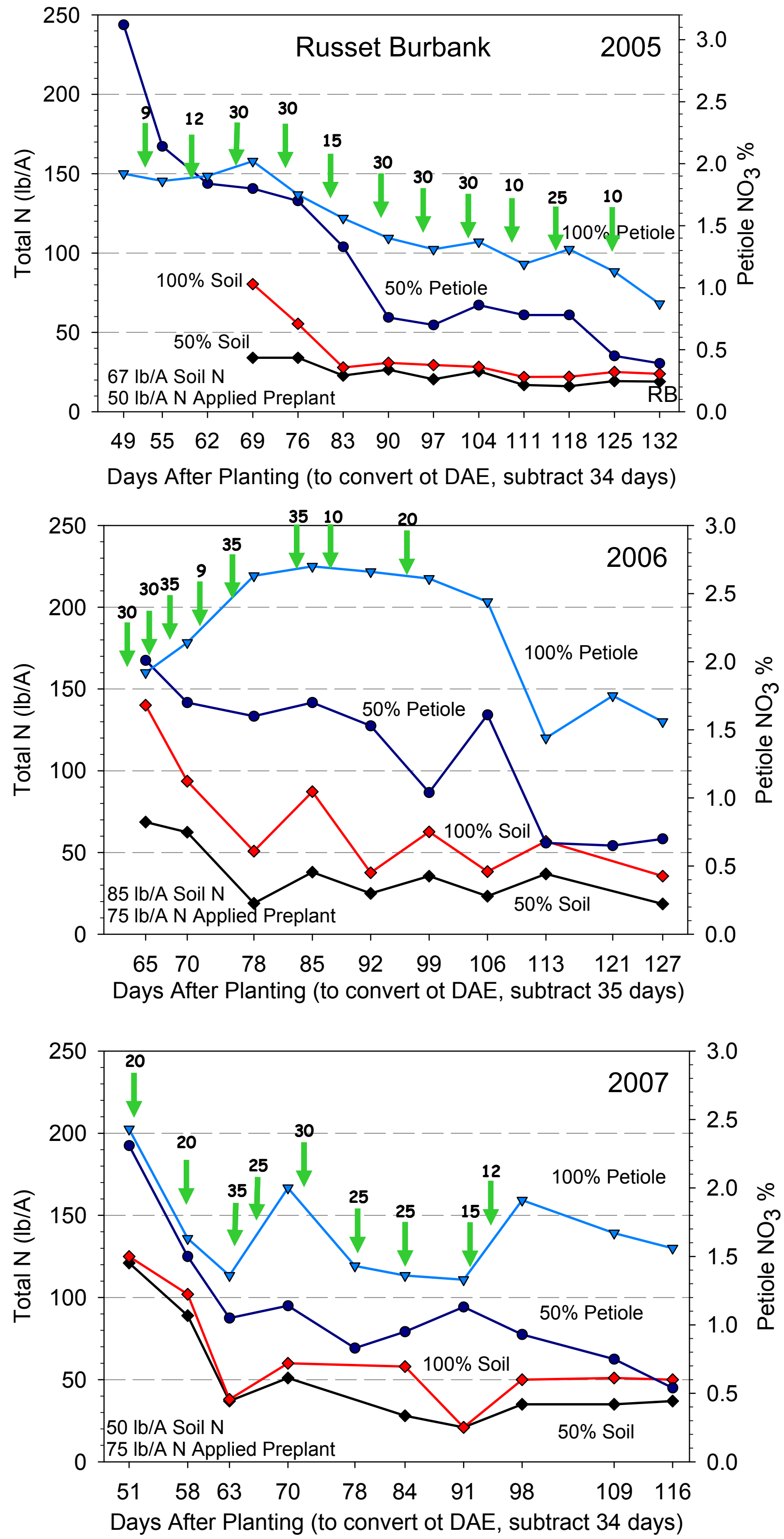

Figure 1. RB petiole NO3-N concentration and available soil N for two different in-season N treatments (50% and 100% of RB recommended in-season N) during 2005-07. In-season N application dates and lbs/A are shown with the green arrows. Distinct differences in the petiole concentrations, and occasionally the soil N, demonstrate that the fertigation simulator is a reliable research method for simulating water-applied in-season nutrient applications.

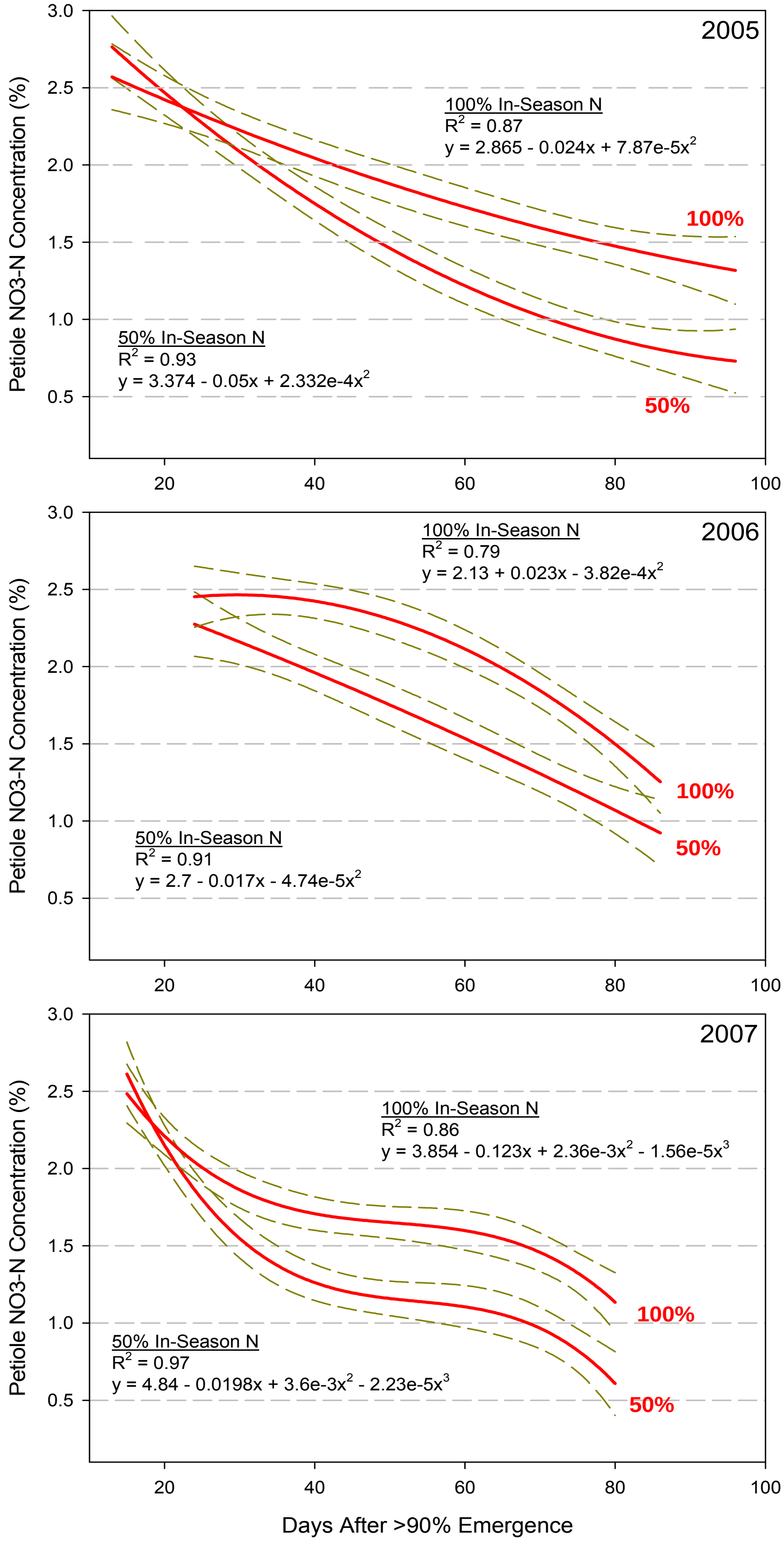

Figure 2. Changes in petiole NO3-N concentrations for 50% and 100% in-season N fertilizer regimes averaged across all cultivars. Petiole values are regressed across days after >90% emergence each year. Despite application of the same in-season quantities of N, each year is unique due to many uncontrollable factors, such as climate, seed source, disease pressure, soil chemistry, etc. Dashed lines indicate 95% confidence intervals.

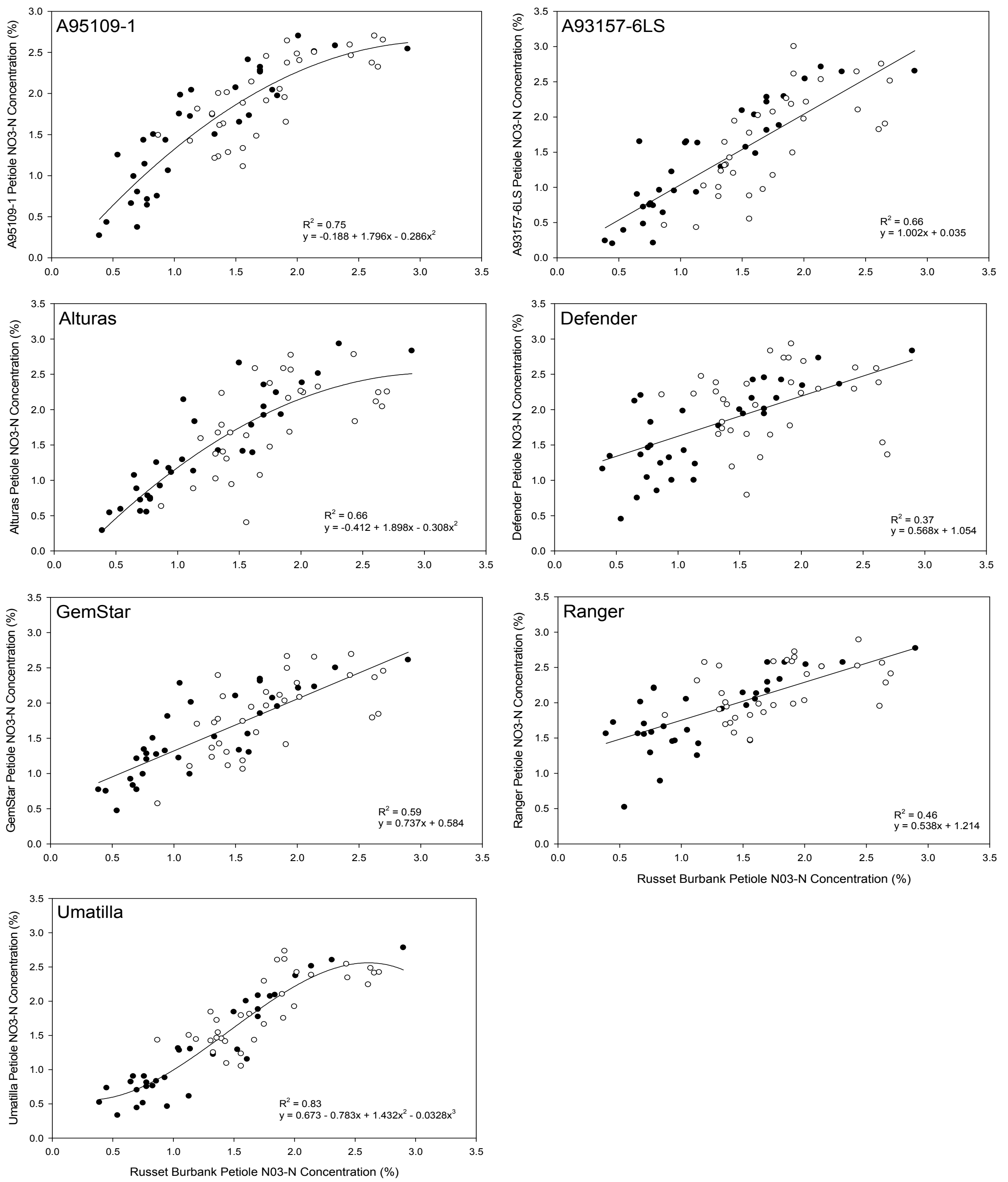

Figure 3. Correlation between the petiole NO3-N concentrations of RB and each of seven other cultivars. These graphs demonstrate how the petiole concentrations of each cultivar fluctuate relative to those of RB when grown under the same in-season N regime. The higher the R^2 value, the stronger the correlation is between RB and a particular cultivar. Each dot represents the petiole concentration from an analyzed sample which was collected during 2005-07. Black dots represent the 50% treatments and white represent the 100% treatments.

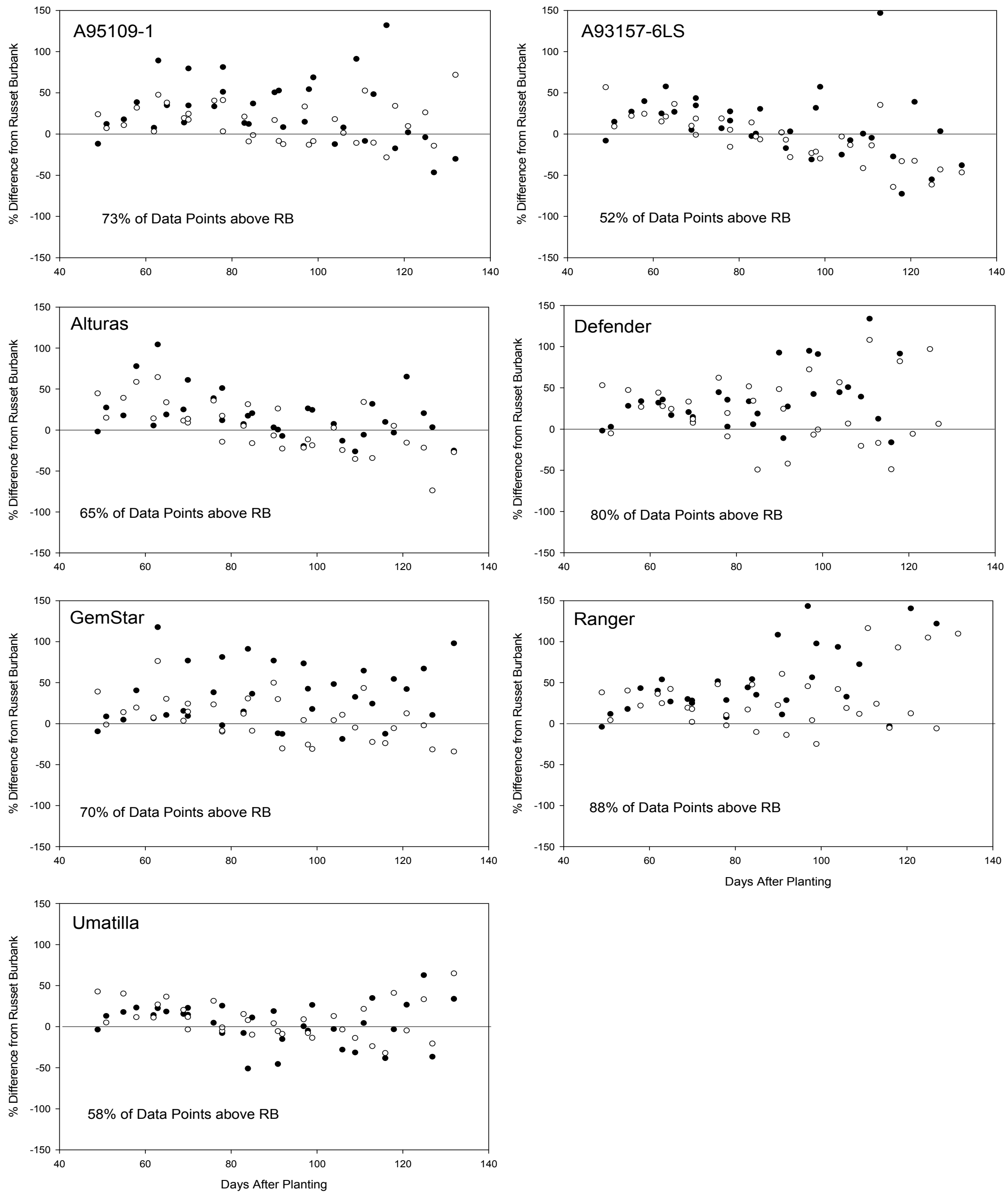

Figure 4. NO3-N petiole concentration differences from RB for each cultivar. Petioles were collected weekly during the 2005-07 growing seasons and the percent difference from RB at each collection date across three years is shown in the graphs. These graphs demonstrate the relationship between petiole concentrations of each cultivar and RB when they are planted at the same time and grown under the same in-season nutrient regime. Each dot represents the petiole concentration from an analyzed sample. Black dots represent the 50% treatments and white represent the 100% treatments.

Table 1. Effects of in-season N rate on plant growth and development.

Cultivar	In-Season N Fert Rate %	Length to Width Ratio	50 Day STAND (% Emerged)	Stem No. Per Plant	(Final Harvest) Average Tuber Weight (Ounces)	(Final Harvest) Average Tuber Number (Tubers/Plant)	Mid Season Harvest Index (Tubers % of Plant Wt)	Pre Harvest Vine Senescence (% Dead Vines)
Alturas	50	1.44	96	3.1	6.9	11.0	57	**23 a**
Alturas	100	1.41	95	2.6	6.6	11.0	54	**16 b**
Defender	50	1.70	97	2.7	9.0	8.4	68	**69 a**
Defender	100	1.71	99	2.8	8.4	8.7	64	**60 b**
Gemstar	50	1.57	82	2.2	8.5	6.5	**70 a**	67
Gemstar	100	1.52	85	2.3	9.9	6.5	**60 b**	62
Ranger	50	1.74	97	1.9	9.2	7.6	**69 a**	**61 a**
Ranger	100	1.72	98	2.3	8.4	8.0	**64 b**	**59 b**
RB	50	1.70	99	2.1	7.3	8.5	71	90
RB	100	1.74	98	2.1	7.5	8.3	72	88
Umatilla	50	1.76	98	3.2	6.1	10.2	74	**88 a**
Umatilla	100	1.74	97	3.0	6.6	10.3	70	**79 b**
A93157-6LS	50	1.51	97	2.7	8.2	8.4	65	61
A93157-6LS	100	1.52	98	3.0	8.6	8.3	63	56
A95109-1	50	1.57	96	2.2	8.8	6.9	68	**79 a**
A95109-1	100	1.59	97	2.1	10.5	6.5	68	**72 b**
All Varieties	50	1.62	95	2.5	8.0	8.5	**68 a**	**68 a**
All Varieties	100	1.63	96	2.5	8.3	8.5	**65 b**	**61 b**

* Percent values may not total 100% due to rounding. For each cultivar, values are not significantly different unless they are followed by different letters. Data were analyzed using Fisher's LSD Test at the 5% level. Significant differences are bolded.

Table 2. Effects of in-season nitrogen rate on yield and economic value of eight potato cultivars, averaged across 2005, 2006, and 2007. Differences between the two treatments for each cultivar are not significantly different unless followed by a different letter.

2005-2007 WSU IN-SEASON NITROGEN X VARIETY TRIAL - Averaged Across Years

Cultivar	In-Season N Fert Rate %	TOTAL YIELD (CWT/A)	US # 1's* > 4 oz (% of Total Yield)	US # 2's* > 4 oz (% of Total Yield)	Culls* & < 4 oz (% of Total Yield)	CARTON YIELD 100-50 count (US 1's 7-18 oz) % of Total Yield	CARTON YIELD (CWT/A)	PROCESS YIELD US 1's and 2's > 6 oz % of Total Yield	PROCESS YIELD (CWT/A)	Fert-Expense-Adjusted Gross $/A, % difference from 100 % Treament: Fresh**	Fert-Expense-Adjusted Gross $/A, % difference from 100 % Treament: Process
Alturas	50	875	78	7	16	49	440	79	610	na	1.1%
Alturas	100	890	79	6	16	48	435	78	660	na	-
Defender	50	810	78	7	15	49	390	86	600	na	-3.0%
Defender	100	840	81	6	13	50	430	87	650	na	-
Gemstar	50	640	90	2	8	59	380	88	525	na	-2.0%
Gemstar	100	690	90	1	9	57	395	88	560	na	-
Ranger	50	780	85	6	9	57	440	87	630	na	3.3%
Ranger	100	765	85	6	9	56	425	87	610	na	-
RB	50	715	73	8	19	45	320	80	475	-0.7%	3.2%
RB	100	710	75	8	17	47	330	82	490	-	-
Umatilla	50	**710 b**	80	4	17	48	**340 b**	**74 b**	**450 b**	na	**-8.8% a**
Umatilla	100	**780 a**	82	4	14	50	**390 a**	**78 a**	**540 a**	na	**0.0% b**
A93157-6LS	50	780	88	2	10	63	495	88	630	2.1%	-1.2%
A93157-6LS	100	820	88	3	9	60	495	89	670	-	-
A95109-1	50	690	91	2	7	**65 a**	448	89	580	1.2%	4.2%
A95109-1	100	745	90	3	7	**61 b**	452	91	635	-	-
All Varieties	50	**750 b**	83	5	13	54	410	**83.6 b**	**560 b**	-1.0%	-0.6%
All Varieties	100	**780 a**	84	5	12	54	420	**84.7 a**	**595 a**	-	-

* Percent values may not total 100% due to rounding. For each cultivar, values are not significantly different unless they are followed by different letters. Data were analyzed using Fisher's LSD Test at the 5% level. Significant differences are bolded.

**Fresh market value differences not shown for varieties unlikely to be sold on the fresh market - indicated with "na" (not applicable).

Table 3. Effects of in-season nitrogen rate on tuber yield and quality of eight potato cultivars, averaged across 2005, 2006, and 2007. Differences between the two treatments of each cultivar are not significantly different unless followed by a different letter.

Cultivar	In-Season N Fert Rate %	US # 1 YIELD > 4 oz (CWT/A)	4-7 oz*	7-14 oz*	> 14 oz*	SPECIFIC GRAVITY	INTERNAL DEFECTS (%) (8-12 oz tubers) % HH	% BC	% IBS	BRUISE (%) (8-12 oz tubers) Blackspot	Shatter
			——— % ———								
Alturas	50	685	30	52	18	1.088	1	1	4	15	49
Alturas	100	700	34	50	15	1.086	0	3	3	19	52
Defender	50	640	22	47	31	**1.087 a**	1	0	1	34	60
Defender	100	680	20	49	31	**1.085 b**	0	0	2	24	62
Gemstar	50	575	20	50	31	1.087	6	0	1	34	71
Gemstar	100	630	18	47	35	1.085	3	1	1	26	67
Ranger	50	660	21	49	27	1.087	0	1	2	25	40
Ranger	100	650	20	50	31	1.086	0	0	2	35	46
RB	50	525	29	52	23	1.083	5	**11 b**	7	24	**43 b**
RB	100	530	28	49	23	1.081	6	**21 a**	8	24	**71 a**
Umatilla	50	**560 b**	**33 a**	51	16	1.084	0	0	2	34	48
Umatilla	100	**640 a**	**28 b**	50	23	1.086	1	0	3	34	57
A93157-6LS	50	685	20	53	27	1.091	2	0	5	27	55
A93157-6LS	100	720	17	49	33	1.089	1	0	3	37	51
A95109-1	50	630	18	53	29	1.081	0	0	**0 b**	16	58
A95109-1	100	670	18	49	33	1.080	0	1	**7 a**	25	68
All Varieties	50	**620 b**	24	**51 a**	**25 b**	**1.0860 a**	2	**1.6 b**	3	26	**53 b**
All Varieties	100	**650 a**	23	**49 b**	**28 a**	**1.0848 b**	1	**3.3 a**	4	28	**59 a**

* Percent values may not total 100% due to rounding. For each cultivar, values are not significantly different unless they are followed by different letters. Data were analyzed using Fisher's LSD Test at the 5% level. Significant differences are bolded.