# Nitrogen Fertigation in Potatoes: Application Timing, Rate, and Varietal Response

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## INTRODUCTION

The concept of applying fertilizer or chemicals via overhead irrigation (fertigation or chemigation) is absolutely ingenious. It requires relatively little man-power compared with an application from a pull-type applicator or broadcast sprayer, there is no need for a tractor, airplane, or sprayer, and the plants and soil are left undisturbed. Moreover, drift is minimal and precision is high.

Basic plant nutrient research during the mid-1800s likely planted the seed for modern day fertigation (Hoagland and Arnon 1950). Researchers grew plants in sand or water using various soluble fertilizer solutions. In the 1930's, Hoagland refined practices and solutions used by the 1800s researchers and developed a soluble fertilizer solution called 'Hoagland's Solution' (Hoagland and Arnon 1950). The solution was the first widely-used nutrient composition and was designed to provide nutrients similar to that of the most productive soils.

The concept of using existing irrigation systems to simultaneously apply fertilizer and other fluids began in the 1960s, according to the website of a modern company, Agri-Inject. They claim that the founder of Agri-Inject, Gary Newton, developed the technology and founded the company in 1983. Presently, Agri-Inject continues to develop and refine chemigation fluid application technology.

Although fertigation has been used commercially on potatoes for several decades, questions remain. The questions have more to do with the outcome of nutrient application practices via fertigation rather than the mechanics of the application. Common questions include: When is the best time to begin fertigation? How much should I apply each time I fertigate? How do different varieties respond to fertigation?

In an attempt to gain a more thorough understanding of N fertigation timing and rate and how they relate to potato growth and development, variety, and harvest date, multiple research trials were conducted near Othello, WA from 2006 to 2011, and the results analyzed. Not all data were included in this report, but major findings are discussed in the summary where relevant.

## IN-SEASON NITROGEN APPLICATION TIMING TRIALS:

**1) Late Harvest In-Season Nitrogen Application Timing with Ranger R., Umatilla R., and Premier R.** (For additional data and information see N.R. Knowles 2008-10 WA State Potato Commission progress reports).

**Purpose:** Identify best in-season N application timing to maximize profits from three late-harvest varieties.

**Background:** Three application regimes of in-season N were applied to Ranger, Umatilla, and Premier (Table 1). The amount of pre-plant and in-season N, P, and K were identical, the only thing that was altered was the in-season N timing. Treatment 1 was designed to give the plants an early start, treatment 2 was a more typical distribution of in-season N, while treatment 3 was designed to provide a late-season N kick and delay vine senescence.

**Table 1.** In-season nitrogen application timing and rates for Late-Harvest trial.

| | N lbs per and number of application | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7 DAE | 14 DAE | 21 DAE | 28 DAE | | | | | | | | | TOTAL | Full Season |
| | 2-4" Plants | 6-8" Plants | | Row Closure | | | | | | | | | IN-SEASON | Target |
| Treatment | 5/28 | 6/4 | 6/11 | 6/16 | 6/19 | 6/24 | 6/30 | 7/7 | 7/14 | 7/21 | 7/28 | 8/4 | 8/11 | N | N |
| 1 | 20 | 20 | 35 | 35 | 35 | 35 | 30 | 20 | 0 | 0 | 0 | 0 | 0 | 230 | 330 |
| 2 | 0 | 10 | 15 | 25 | 35 | 35 | 35 | 25 | 20 | 15 | 15 | 0 | 0 | 230 | 330 |
| 3 | 0 | 0 | 0 | 10 | 15 | 25 | 30 | 35 | 35 | 30 | 20 | 20 | 10 | 230 | 330 |

**Results:** Each year, the soil N was between 125 – 150 lbs/A prior to planting. Petioles and soils were collected routinely (Figure 1). Despite the extreme differences in in-season N application timing, there was no timing that provided the best yield (Figure 2) nor economic value (data not shown) consistently. What this likely indicates is that across the duration of this study, the pre-plant soil N level of 125-150 lbs/A was adequate to carry the plant growth and development into late June (when the late applications began) without any detriment to the yield or economics. Early N applications were utilized by the rapidly growing plant, stored in the soil, and/or leached, but the levels getting to the plants were adequate to provide full season yields through early vine growth and plant utilization. See also N.R. Knowles' discussion on Ranger N Timing within the WA State Potato Commission Research Progress Reports between 2008-10 as he goes into more detail on the plant's growth, development, and physiology throughout the season.

**2) Early Harvest In-Season Nitrogen Rate x Application Timing with Blazer Russet, A0008-1TE (one year) and AO96141-3 (two years) 2008-2010.**

**Purpose:** Identify best in-season N application timing and rate to maximize profits from two new early-harvest varieties.

**Background:** Information on in-season N application rate and timing for early harvested in the Columbia Basin has gone unreported, especially for new varieties. New varieties that may find a fit in early production, Blazer Russet, A0008-1TE and AO96141-3, were grown under four different rate/application regimes (Table 2). Treatment 1 was a high-rate stair-step type regime, treatment two was a lower rate stair-step type regime designed to terminate by end of June. Treatment 3 was the same rate as treatment 2 but was a lower, more constant rate lasting into July. Treatment 4 received no in-season. All treatments had the same pre-plant nutrients available – with soil residual – including pre-plant/soil residual N values of approximately 100 lbs/A.

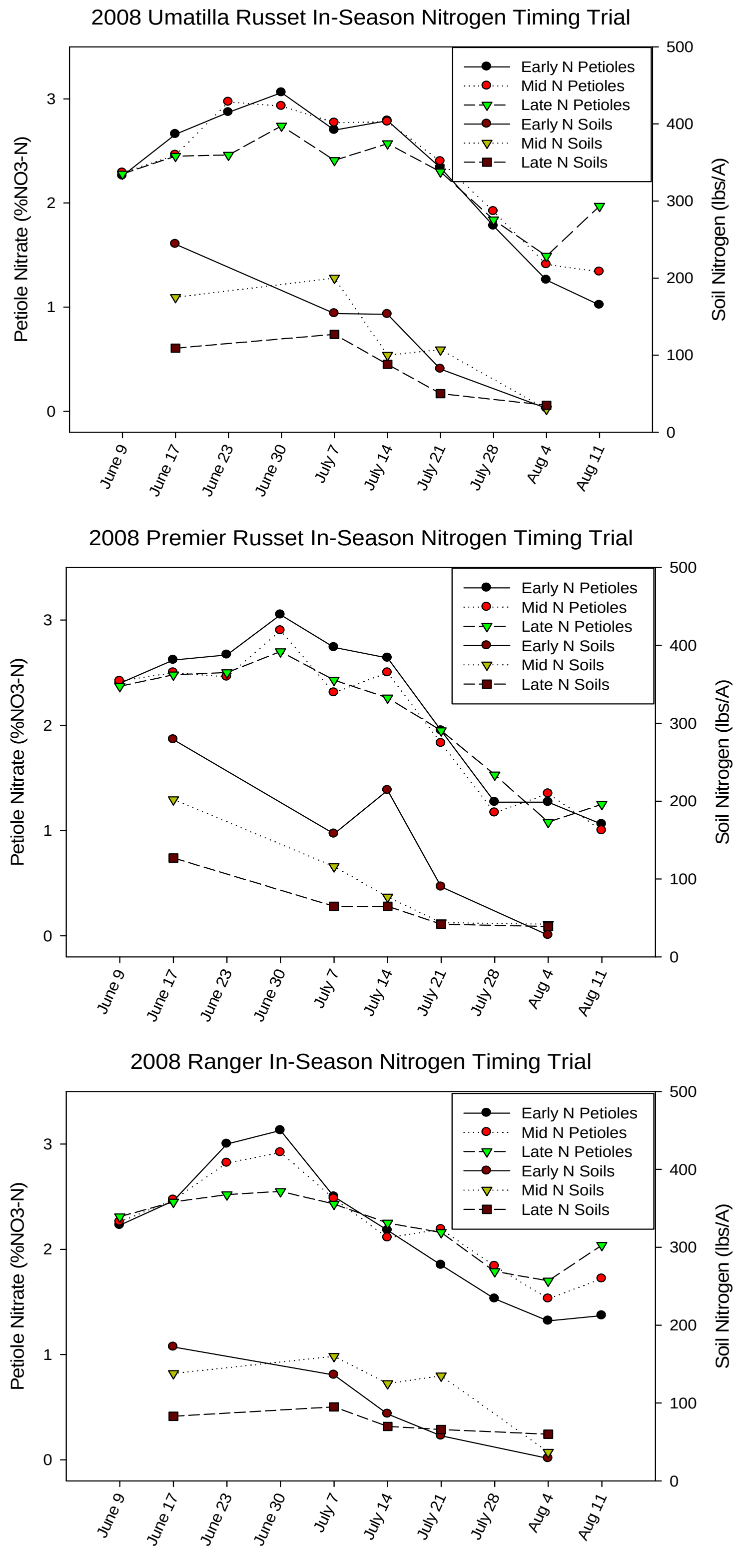


**Figure 1.** Petiole nitrate and soil N (1 ft depth) values for Umatilla, Premier, and Ranger from the 2008 Late-Harvest In-season N Application Timing Study.

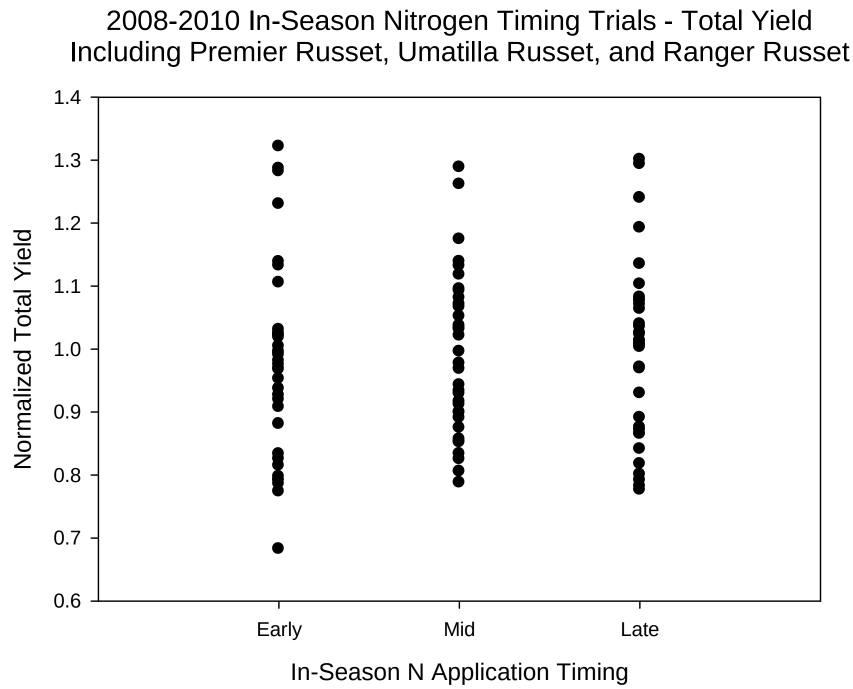


**Figure 2.** Normalized total yield for Premier, Umatilla, and Ranger for three different N application timing intervals

**Table 2.** Rates and application dates of 2009 early harvest nitrogen application timing trial with Blazer Russet and AO96141-3.

| | N lbs per and number of application | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7 DAE | 14 DAE | 21 DAE | 28 DAE | | | | | | TOTAL | Full Season |
| | 2-4" Plants | 6-8" Plants | | Row Closure | | | | | | IN-SEASON | Target |
| Treatment | 5/28 | 6/4 | 6/11 | 6/16 | 6/19 | 6/24 | 6/30 | 7/7 | 7/14 | 7/21 | N | N |
| 1 | 20 | 20 | 35 | 35 | 35 | 35 | 30 | 20 | 0 | 0 | 230 | 330 |
| 2 | 20 | 20 | 35 | 35 | 20 | 0 | 0 | 0 | 0 | 0 | 130 | 230 |
| 3 | 0 | 10 | 20 | 20 | 20 | 20 | 20 | 20 | 0 | 0 | 130 | 230 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 130 |

**Early Harvest In-Season N Timing Results:** Similar to the late harvest N application timing trial, the pre-plant soil N (~125-150 lbs/A) appeared to have been mostly adequate to support the plant growth and maturity late into July, when plants were vine-killed and harvested. The petioles and soils showed the treatment differences, with the high N rate – early timing treatment producing the highest N concentrations in the petioles (Figure 3), and likely the heaviest vines (data not shown). The pre-plant only treatment (treatment 4) was the top yielder and income producer during 2008-09 (Table 3) and the specific gravity from this treatment was among the highest. The lack of in-season N influenced the plant from treatment 4 to produce more tubers per plant than the other treatments. For treatments with in-season N applications, the extra N likely reduced specific gravity by delaying plant maturity; in-turn, the plants produced fewer tubers as the vines were likely the focus of plant growth through most of June. During 2010, there were few significant differences, but all in-season treatments produced higher >6 oz market yield and average tuber weight than the no-in-season N treatment – just opposite the previous two years. The yearly differences indicate that the climate of a given year plays a major role in the outcome of early potato production. A0008-1TE out-produced the other cultivars but its specific gravity was a bit lower than the other two cultivars (Table 3). No differences were seen among treatments for vine senescence just prior to harvest (data not shown).

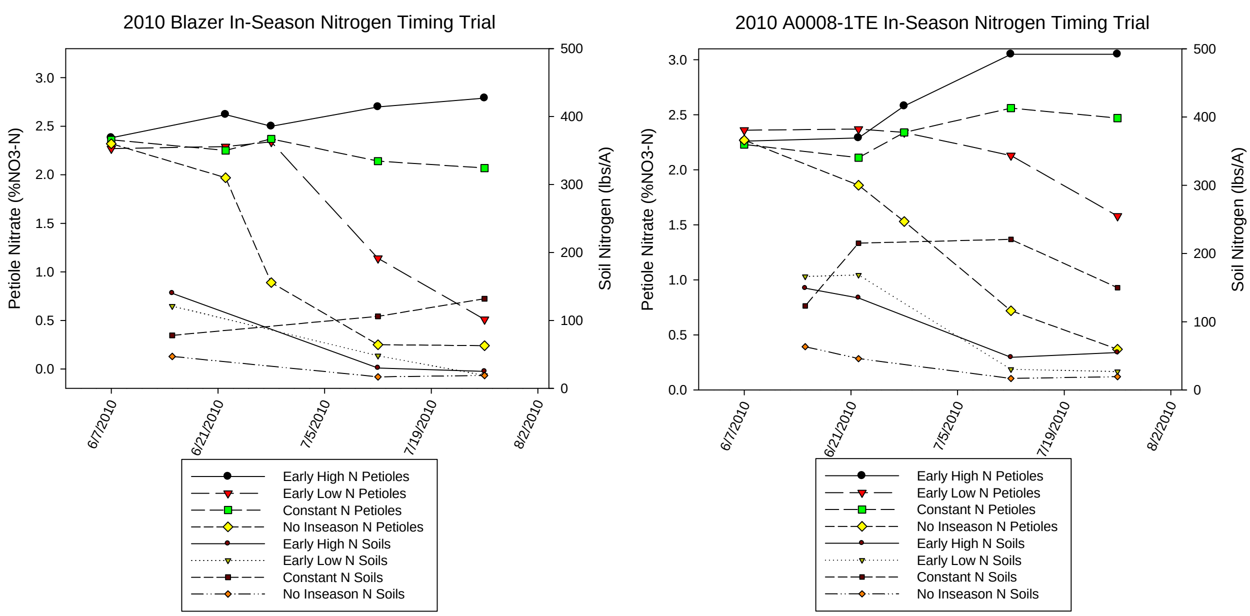


**Figure 3.** Petiole nitrate concentrations and soil nitrogen (1 ft depth) for two early-harvest varieties treated with different in-season N timing intervals.

**Table 3.** Early harvest in-season N timing trial results averaged across years, varieties, and treatments for 2008-2010.

| Variety* | 2008-09 Averaged across Blazer and AO96141-3 Treatment | Treatment Number | Total Yield | Market Yield 6 oz | > 6 oz | N Fert Expense Adjusted Gross | Tuber Number per Plant | Average Tuber Weight | Specific Gravity |
|---|---|---|---|---|---|---|---|---|---|
| | | | CWT/A | | % | $/A | | oz | |
| All Varieties | Early Kick, High Rate | 1 | 435b | 247 | 56 | 2860b | 8.23ab | 8.0 | 1.07983b |
| | Early Kick, Low Rate | 2 | 430b | 257 | 59 | 2967b | 7.88b | 8.3 | 1.08359a |
| | Constant Rate | 3 | 441ab | 258 | 59 | 3039b | 8.12b | 8.3 | 1.08140ab |
| | No-Inseason N | 4 | 469a | 277 | 59 | 3324a | 8.72a | 8.3 | 1.08290ab |
| | *P* Value (0.10) | | 0.0914 | ns | ns | 0.0050 | 0.0462 | ns | 0.0818 |

| Variety* | 2010 Averaged across Blazer and A0008-1TE Treatment | Treatment Number | Total Yield | Market Yield 6 oz | > 6 oz | N Fert Expense Adjusted Gross | Tuber Number per Plant | Average Tuber Weight | Specific Gravity |
|---|---|---|---|---|---|---|---|---|---|
| | | | CWT/A | | % | $/A | | oz | |
| All Varieties | Early Kick, High Rate | 1 | 605 | 450a | 75a | 4290 | 7.8 | 10.82a | 1.07986b |
| | Early Kick, Low Rate | 2 | 604 | 454a | 75a | 4398 | 7.6 | 10.94a | 1.08053b |
| | Constant Rate | 3 | 591 | 430a | 73a | 4260 | 7.6 | 10.78a | 1.07646c |
| | No-Inseason N | 4 | 573 | 373b | 65b | 4193 | 8.2 | 9.66b | 1.08336a |
| | *P* Value (0.10) | | ns | 0.0148 | 0.012 | ns | ns | 0.0327 | <0.0001 |

| | Variety** | | Total Yield | Market Yield 6 oz | % > 6 oz | N Fert Expense Adjusted Gross | Tuber Number per Plant | Average Tuber Weight | Specific Gravity |
|---|---|---|---|---|---|---|---|---|---|
| | | | CWT/A | | % | $/A | | oz | |
| | AO0008-1TE | 2010 | 570a | 411 | 72 | 4145a | 7.5 | 10.6 | 1.080c |
| | AO96141-3 | 2008-09 | 449c | 262 | 58 | 3097b | 8.2 | 8.2 | 1.087a |
| | Blazer R. | 2008-09 | 498b | 319 | 63 | 3474b | 8.2 | 9.0 | 1.082b |
| | *P* Value (0.10) | | 0.0220 | ns | ns | 0.0532 | ns | ns | 0.0001 |

*Main effect of treatment, averaged across all varieties
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***Values followed by no letter or the same letter are not significantly different at the p = 0.10 level.

## SUMMARY

Why not apply all fertilizer pre-plant or early in the season and be done with it for the rest of the year? Those who have listened or read about issues related to commercial farming and ranching across the past 20 years or so, understand that nitrate in our ground water is a real concern and commercial agriculture is largely to blame. When large quantities of N are applied at planting, the nutrient ($NO_3$) becomes vulnerable to leaching. In addition, urea (46-0-0) application leads to a high potential of N loss via ammonia volatilization where dissolved ammonia converts to ammonia gas. Volatilization is bad because it can lead to a higher use of N, thereby reducing the grower’s bottom line, and the gas becomes an environmental concern by increasing atmospheric ammonia. By applying N through fertigation, growers have the ability to adjust nutrient applications in sync with plant demand via soil and petiole data. In a sense, the plants are “spoon-fed,” getting what they need, when they need it.

One major question is “when should we start fertigating?” The answer may vary depending on who you talk to. It is possible to start too early by applying nutrients the plant isn’t ready to use. It is also possible to get caught with your pants down, so to speak, by waiting until the plants begin growing rapidly to supplement the soil which results in playing catch-up for several weeks. Some agronomists actually theorize that you must “starve” a plant until after tuberization to encourage early tuberization and an increase in tuber number per plant. The theory is that when young plants grow in a N-deficient soil they identify the nutrient stress and focus energy toward tuber production that is supposed to lead to higher yields. Moreover, some believe it will also reduce internal defects and restrict vine size, claiming “excessive vine growth is bad!”

Based on nutrient research conducted across the past six years, we found that starving a plant may actually restrict yield if the canopy size is reduced (Figure 4). In addition, we have found it difficult to starve a young plant to the point of altering tuber number or affecting vine growth safely. Keeping a plant healthy and happy by feeding it what it needs as it needs it, is key to profitable potato production. Many get confused about excessive vine growth (luxury N consumption) being bad, because it can reduce yield. The important thing to remember is that plants often seen as producing “excessive” vine growth early- to mid-season achieve spectacular yields if allowed enough time to mature naturally. This means cutting off and depleting the soil of N after vines have peaked, about mid- to late-July in the Columbia Basin, so the plant can begin natural senescence. If “excessive” vine growth happens at the end of the growing season, when tubers should be bulking and vines senescing, you may reduce yield potential.

Recommendations developed from the Late Harvest In-Season N Timing Trial and other studies are to begin applying N sometime between early to late June to reduce leaching issues, provided you have 125-150 lbs/A N already in the soil. Otherwise, you should start feeding the plants just prior to rapid vegetative growth; perhaps when plants are about 10 inches tall. As a tool for deciding when to start applications, it is important to look at the forecast for the next week to assess how fast potatoes might grow and what their needs might be.

Because year-to-year differences were seen in the Early Harvest Timing Trial, it becomes important to decide if 1) you need to apply in-season N for an early harvest and 2) when to start and 3) when to finish. Our recommendation is to avoid early excessive N, especially for an early harvest. These data indicate that adequate soil levels of N prior to planting (~125-150 lbs/A) will produce comparable early yields and economics to potatoes grown with additional in-season N. However, if the growing conditions during certain years are ideal, early harvest producers may consider applying some in-season N during June to ensure an adequate supply for rapidly growing vines under ideal conditions. Also, growers in locations with longer early-seasons than Othello, WA, will likely benefit from some in-season N during June. For harvest of around 100 days after planting, 150 to 200 lbs N, should be adequate to maximize production and profitability within most growing seasons in the Columbia Basin. Growers should consider applying in-season N most years if they don’t think the soil will provide 200 lbs/A N to the plants. Similar to recommendations for late harvest production, the applications should begin early to late June or when plants are about 10 inches tall.

To maximize economic return, it is important that plants are allowed to mature naturally. N applications close to harvest are not recommended. Excessive N late in the season will delay plant maturity and encourage vine growth, not tuber growth. Rapid, full vine growth is beneficial and recommended early in the season; it should be avoided late in the season. Excessive late season N will reduce yield, specific gravity, and economic return. Three to four weeks prior to harvest, the soil N should be at or below 50 lbs/A and in-season N applications should be terminated. When it is all said and done, it is important to remember that our goal is not to produce the highest yield; it is to produce the most profitable yield.

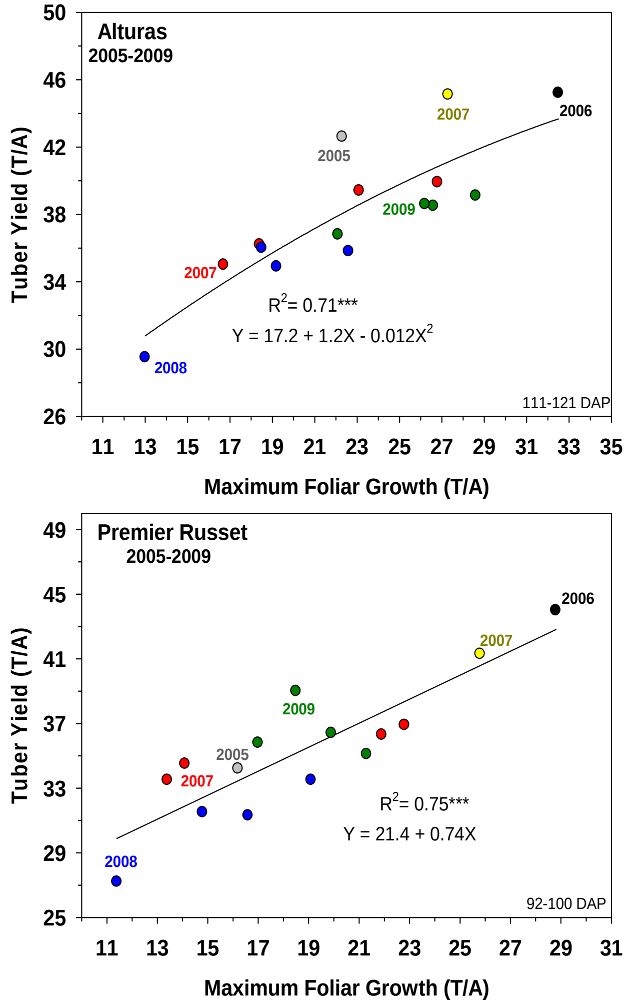


Figure 4. Tuber yield by maximum foliar growth from various research trials conducted between 2005 and 2009 at the WSU Othello Research Farm. Figure provided by N.R. Knowles

## REFERENCE

Hoagland, D.R. and D.I. Arnon. 1950. The water-culture method for growing plants without soil. California Agricultural Experiment Station Circular 347:1-32.