STACKING NUTRIENT 4Rs ON POTATO AND WHEAT

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ABSTRACT

The 4Rs of nutrient management are research-based guidelines with the aim to improve the sustainability of major cropping systems and the environment without compromising crop yield and quality. The objective for this project is to evaluate individual and stacked 4R management practices and how they intersect. A field trial near Grace, Idaho was conducted on potato (*Solanum tuberosum* L.) in 2020 and hard white spring wheat (*Triticum aestivum* L.) in 2021. Nitrogen (N) fertilizer treatments included all combinations of two sources (uncoated vs polymer coated urea (PCU)), two rates (100 or 75%), two timings (emergence or split applied), and two placements (broadcast or band + broadcast) compared to an untreated control. Overall, potato was responsive to N, but the wheat was not (which is common when following potato). Despite large numerical increases for all treatments compared to the unfertilized control (50-129 cwt ac^{-1}), only the source (PCU) treatment was significantly different (144 cwt ac^{-1}). It is also noteworthy that the reduced rate of urea performed identically to the full rate of urea. Although this is a limited amount of data, it reinforces the 4R principles and suggests that stacking some methods may not be necessary. For example, a timing component did not provide further increase when an enhanced efficiency source was used. Future trials are planned to continue this investigation.

INTRODUCTION

Crops cannot take up all plant available N at once (Gayler et al., 2002). Therefore applying a full rate of nitrogen (N) fertilizer all before the plant emerges is problematic (Hopkins et al., 2020). The N in fertilizer can quickly become unavailable to plants through the processes of volatilization, denitrification, and leaching (Hopkins et al., 2020). Therefore, N fertilization is not completely efficient.

Implementing the 4Rs of nutrient management potentially increases yields, crop quality, and/or profits while reducing environmental risk (Hopkins et. al, 2020). The 4Rs include applying the “right” rate of fertilizer using the “right” source at the “right” timing and placement (Flis, 2020). A plethora of scientific studies have developed and vetted these practices that have been shown to work in field conditions with growers. However, there are only limited studies where two or more of the 4Rs are included at the same time and none that we know of where all four have been tested in concert with each other.

For example, the Grower’s Standard Practice (GSP) for potato involves split application of N fertilizer with 25-50% typically applied preplant and/or at cultivation with the remainder injected in the irrigation water, based on petiole nitrate-N analysis, periodically during the growing season. Many studies have resulted in understanding the correct rate. Other studies have evaluated Enhanced Efficiency Fertilizers (EEF), such as polymer coated urea (PCU). Some studies show that less fertilizer needs to be applied when using a PCU due to the increased Nitrogen Use Efficiency (NUE). The improved efficiency of PCU also potentially reduces the need to split apply fertilizer, which may save time and equipment and fuel costs. Although there are limited studies evaluating these practices with PCU, there is not sufficient data examining if the timing and rates need to be adjusted.

The 4Rs are also effective at mitigating nitrogen losses to the environment. Applying a reduced rate of fertilizer automatically decreases the amount of N that could be lost to the environment. PCU has also proven effective at reducing N lost to the atmosphere through volatilization and to groundwater through leaching (Hopkins et al., 2020). As more farmers begin to implement the 4Rs of nutrient management, we expect to see less N pollution in the environment from agricultural sources.

The objective for this project is to evaluate individual and stacked 4R management practices for potato and wheat and how they intersect, including all combinations of two sources (uncoated vs polymer coated urea (PCU)), two rates (100 or 75%), two timings (emergence or split applied), and two placements (broadcast or band + broadcast) compared to an untreated control.

MATERIALS AND METHODS

Irrigated Russet Burbank potato (*Solanum tuberosum* L.) and Dayn hard white spring wheat trials were conducted in 2020 and 2021, respectively, in a field near Grace, Idaho, USA on calcareous sandy loam soil. Treatments (Table 1 for potato and Table 2 for wheat) were arranged in a randomized complete block, full factorial design with six replications. For wheat, each of the 4Rs are evaluated in combination with the other practices, but for potato the timing and placement treatments are combined as this better represents what growers actually do.

Table 1: 2020 experimental treatments (potato). Highlighted fields indicate implementation of 4R factors.

Trt #	Treatment	Source (applied at emergence)	N at emergence, kg/ha	N in-season, kg/ha	total N, kg/ha	Rate	Timing/Placement (pre-emerge is PCU or urea; in-season is urea only)
1	Negative Control	n/a	0	0	0	n/a	n/a
2	Positive Control	urea	247	0	247	full	Pre-Emergence
3	Source (S)	PCU	247	0	247	full	Pre-Emergence
4	Rate (R)	urea	207	0	207	reduced	Pre-Emergence
5	Timing (T)	urea	207	40	247	full	Split
6	SxR	PCU	207	0	207	reduced	Pre-Emergence
7	SxT	PCU	207	40	247	full	Split
8	RxT	urea	168	40	207	reduced	Split

9	SxRxT	PCU	168	40	207	reduced	Split

Table 2: 2021 experimental treatments (wheat). Highlighted fields indicate implementation of 4R factors.

Trt #	Treatment	Source	Rate	Time	Place
1	Negative control	n/a	0% YG	n/a	n/a
2	Low	Urea	50% YG	Pre-plant (PP)	BRCST
3	Average (positive ctrl)	Urea	100% YG	PP	BRCST
4	Rate (R)	Urea	75% YG	PP	BRCST
5	Source (S)	PCU	100% YG	PP	BRCST
6	Timing (T) - this is GSP	Urea/UAN	100% YG	PP+Flag leaf (FL)	BRCST+F
7	Placement (P)	Urea	100% YG	PP+Band at planting (AP)	BRCST+BA
		2-way interactions			
8	RS	PCU	75% YG	PP	BRCST
9	RT	Urea/UAN	75% YG	PP+FL	BRCST+F
10	RP	Urea	75% YG	PP+AP	BRCST+BA
11	ST	PCU/UAN	100% YG	PP+FL	BRCST+F
12	SP	PCU	100% YG	PP+AP	BRCST+BA
13	TP	Urea/UAN	100% YG	PP+AP+FL	BRCST+BA+F
		3-way interactions			
14	RST	PCU/UAN	75% YG	PP+FL	BRCST+F
15	RSP	PCU	75% YG	PP+AP	BRCST+BA
16	RTP	Urea/UAN	75% YG	PP+AP+FL	BRCST+BA+F
17	STP	PCU/UAN	100% YG	PP+AP+FL	BRCST+BA+F
		4-way interactions			
18	RSTP	PCU/UAN	75% YG	PP+AP+FL	BRCST+BA+F

Handheld Normalized Difference Vegetative Index (NDVI) were measured (four dates for potato and three for wheat) in-season (GreenSeeker, Trimble Agriculture, Westminster, CO). Composite potato petiole and wheat flag leaf samples were collected and analyzed for nitrate (NO_3^--N) or total N, respectively. Total yield was measured at harvest, along with various quality measurements. Statistical analysis was performed by ANOVA with mean separation using the Tukey Kramer method using SAS software.

RESULTS AND DISCUSSION

Potato was responsive to N, as indicated by an orthogonal yield increase for fertilized treatments over the unfertilized, negative control (P = 0.421). Although the numerical increases in yield were large in magnitude (50-129 cwt ac^{-1}), only the source (PCU) treatment was significantly different at 144 cwt/ac more total yield than the unfertilized control (Fig. 1).

For US No. 1 tuber percentage (data not shown), only the source x timing (ST) treatment was significantly greater at 95% than the unfertilized control at 80%. It was also significantly greater than the rate x timing (RT) treatment also with 80% US No. 1 tubers. All other treatments performed similar to the ST treatment, ranging from 83-93%.

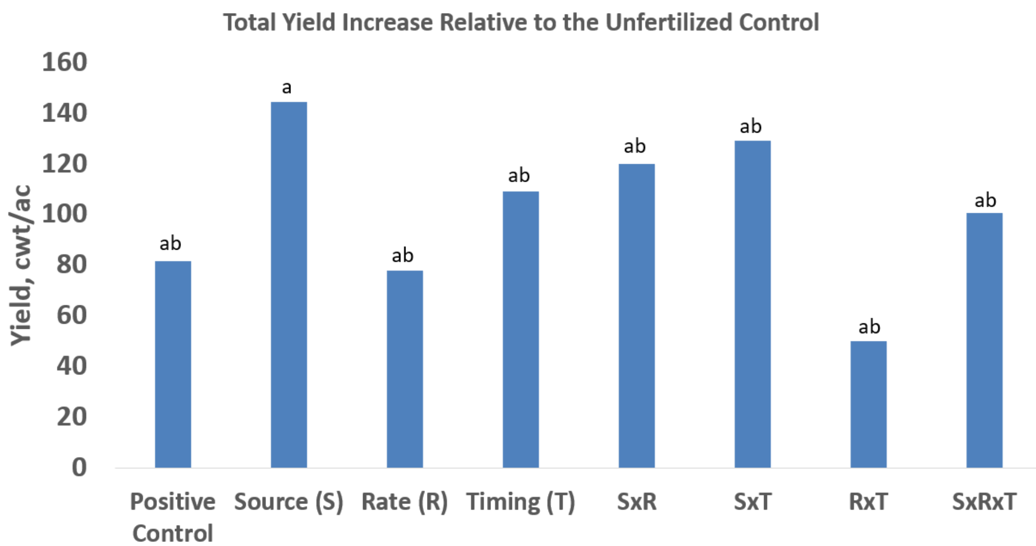

Figure 1. Potato yield increase relative to unfertilized control (its statistical indicator is a “b”). Bars sharing the same letter are not statistically different from one another.

Total yield measurements followed a trend similar to the one seen in petiole nitrate results. For all sampling dates, the petiole NO_3^--N for the unfertilized control was significantly lower than all fertilized treatments (Fig. 2). Almost all other treatments were statistically similar throughout the growing season. However, the positive control was statistically higher than all other treatments.

For NDVI, the negative control performed statistically similar to all fertilized treatments on the first sampling date, but was statistically lower for the remaining sampling dates (Fig. 3). The NDVI values for all fertilized treatments stayed mostly the same for the first three sampling dates. On the fourth sampling date, values differed among the treatments and reached statistical significance. Each treatment with PCU as the fertilizer source performed better than the urea fertilizer treatments, except for the rate treatment on the last sampling date.

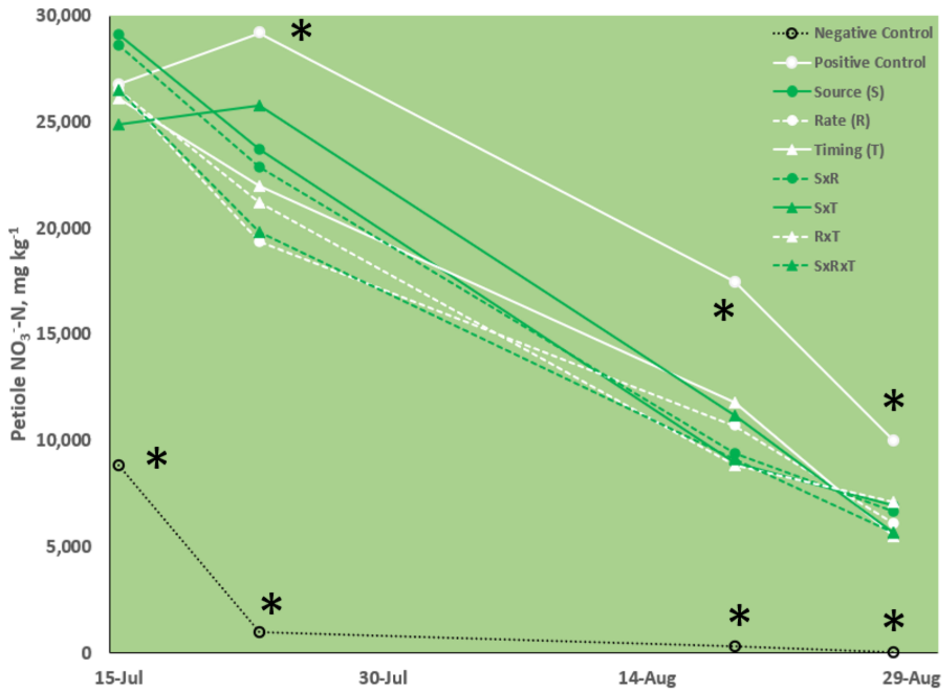

Figure 2. Potato petiole nitrate-N. Asterisks indicate values significantly different than the Grower's Standard Practice (GSP).

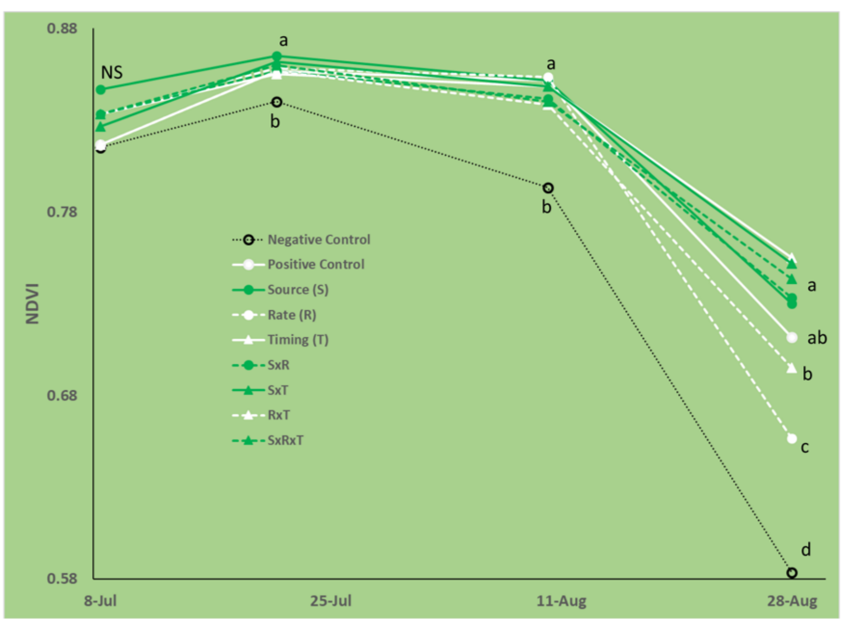

Figure 3. Potato Normalized Difference Vegetative Index (NDVI). Values or groups of values close to one another sharing the same letter are not statistically different from one another. (P = 0.05)

There were no significant differences between any of our treatments for any measurement for wheat. This includes our negative control, which received no N fertilizer at any time in 2021. This is likely because this was a wheat crop following a potato crop. Potato production often results in high residual N in the soil after harvest. (Hopkins et al., 2020). With a root zone deeper than potato, the wheat crop was likely able to access the residual N from previous years. Additionally, in contrast to growing after another grain crop, the crop residue following a potato crop has a low C:N ratio and has a relatively high amount of readily available N. Therefore, it is logical that it takes less N to grow a crop following potato than most other crops. Thus, the wheat was able to be healthy, despite receiving no N fertilizer additions in our negative control plots. This result reinforces the historical success of the 4Rs. Our study shows that farmers can reduce fertilizer rates in certain scenarios and still yield an acceptable crop.

Implications

Our results suggest that implementing the 4Rs of nutrient management can effectively grow healthy potato plants. Each treatment, except for the negative control, resulted in acceptable levels of petiole nitrate and NDVI values. Thus, the 4Rs can serve as reliable guidelines in making management decisions.

The in-season data confirms other findings that PCU is a viable N source for Russet Burbank potato. Each treatment with PCU as the fertilizer source performed as well or better than the GSP. For NDVI, each PCU treatment performed statistically better than the GSP treatment. The relatively higher petiole nitrate and NDVI values are a result of the slow-release technology of PCU.

The polymer coating around PCU fertilizer granules allows moisture from the soil to enter the granule and dissolve the nitrogen. That nitrogen solution then diffuses out of the polymer coating at a rate controlled by the temperature of the surrounding soil (Hopkins et al., 2020). This mechanism allows for the gradual release of N to the plant throughout the growing season. Thus, rather than receiving more N than the plant can use all at once, plants fertilized with PCU are fed with N in smaller amounts over time.

In conclusion, our results indicate that healthy potato plants can be grown by applying the 4R nutrient management principles. Implementing these practices will help farmers save money and time, use natural resources more efficiently, and reduce the impact of fertilizers on the environment.

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