nutrient stewardship

Evaluation of 4R Fertitlity Strategies on Potato in Prince Edward Island 2015 Report

Submitted by: Steve Watts P. Ag.
Genesis Crop Systems Inc

Fertilizer Canada
Fertilisants Canada

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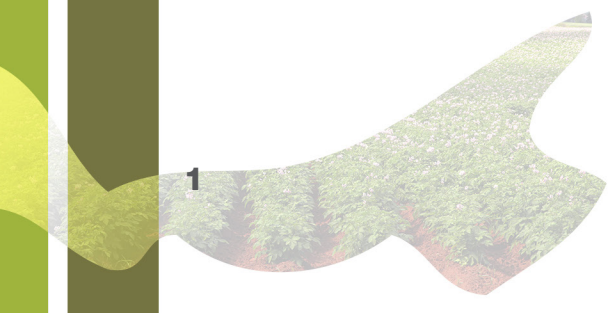

1. Introduction

4R Nutrient Stewardship (the Right Sourceat the Right Rate, Right Time and Right Place®) strategies for fertilizing potatoes under Prince Edward Island (PEI) conditions were introduced to the Island industry in 2013 and 2014 (five & 13 sites, respectively) through a series of field scale demonstration trials conducted by Genesis Crop Systems Inc (GCS) under contract to Fertilizer Canada, formerly the Canadian Fertilizer Institute.

The 4R Nutrient Stewardship Best Management Practices (BMPs) treated field areas produced crops with equivalent or better economic value and quality at the majority of sites evaluated in each of the two seasons. Soil samples collected shortly after harvest revealed less residual NO_{3-} nitrogen in the 4R Nutrient Stewardship treated areas of the field as compared to the Grower Standard Practice (GSP) areas. Overall fertilizer use efficiency was improved where growers applied 4R Nutrient Stewardship program.

Year 1 and 2 results continue to attract increased grower attention. Although official project activities increased slightly to 15 sites in 2015, numerous growers implemented 4R Nutrient Stewardship BMPs on additional acres of their farms. One of the 15 sites had irrigation capacity in 2015; the rest were rain fed.

2. Methodology

GCS engaged 15 PEI producers to participate in the demonstration trials. Participants included:

- MacLennan Properties, West Cape
- Jeff & Jason Smallman, Knutsford
- Link Agro-Services, Linkletter (2)
- Island Holdings, New Annan
- Spring Valley Farms, Spring Valley
- R&L Farms, Shamrock
- Country View Farms, Newton
- Oyster Cove Farms, Hamilton
- Willard Waugh & Sons, Bedeque
- Martin Visser & Sons, Victoria
- Harold Godfrey & Son, Cornwall
- Brian & Scott Annear, Montague
- Mo'Dhaicd'h Farms, Marie
- Rollo Bay Holdings, Rollo Bay

Figure 1 provides an overview of farm locations. Sites were included in all major Island production areas and included crops planted for fresh, processing and seed use. Ten of these farms participated in previous trials and were eager to continue in 2015. Current soil test report data, previous crop history, organic amendment application (if applicable), variety and end use were all factors considered for development of 4R Nutrient Stewardship for each site. Cooperating growers were asked to treat a section in the field at least ten acres in size with the 4R Nutrient Stewardship fertility recommendation protocol. An area of at least equal size and immediately adjacent to the 4R Nutrient Stewardship plot was managed using the grower's traditional fertilizer program (GSP).

Figure 1: PEI Farming 4R Island Demonstration Sites 2015

4R Nutrient Stewardship strategies included:

- Split N applications into two or three applications including reduced levels of N in the planter mix as compared to the GSP treated areas. A number of sites also featured reductions in total N application of 10-20%.

- Reduced levels of P_2O_5 application. Most soils, in potato growing areas of the province have quite high levels of P_2O_5 and likely do not require the level of P_2O_5 application that is currently popular with many growers. Local Agriculture and Agri-food Canada research is concentrating on development of Phosphorous Saturation Indices which may be utilized to assist in identifying if reduced levels of phosphorus application may be feasible in the future.

- Potash (K_2O) was split applied as pre-plant broadcast/incorporated (Muriate of Potash [MOP]) and banded at planting (KMag - Sulfate of Potash). The traditional GSP K_2O program involves almost exclusive use of MOP. This results in increased the salt concentration around the tuber zone. Research has indicated that the chlorine ion in MOP (KCl) may be associated with reducing tuber dry matter content which is an undesirable attribute in potatoes destined for the processing market. Broadcast, rather than banding, application of MOP can help alleviate this effect. Potash levels were adjusted to a rate using current soil test values plus applied rates considered to be effective in replacing the K_2O removed producing a reasonable yield of potatoes for PEI conditions. In some cases, this resulted in a reduction in total lbs K_2O applied; in others an increase, when compared to the GSP treated section of the field.

- Magnesium (Mg), Boron (B) and Zinc (Zn) can be quite low in many Island fields and have been added to programs where soil tests indicated a potential crop response would be possible.

- All growers were asked to avoid application of any foliar fertilizer products on the sections applied with 4R Nutrient Stewardship of the field unless advised by GCS.

- The 4R Nutrient Stewardship plots at several sites (B&O) varied somewhat from all others. Two sites involved the use of ESN Urea applied in place of the standard Urea for the pre-plant broadcast treatment and slow release nitrogen (SRN) was used in place of the standard dry calcium ammonium nitrate (CAN) nitrogen applied just prior to hilling. One other site where the grower traditionally broadcast all of the fertilizer requirements involved the addition of a liquid starter phosphorous product side banded at planting.

- Note that with exception of the last point above, 2015 strategies remained relatively similar to those evaluated in past years with the objective of achieving multi-year repeatability.

GPS reference points were established for each treatment at each site shortly after planting to aid in subsequent petiole, tuber and soil sample collection.

Plant petiole samples were collected from each treatment in each field at full row closure and again three weeks later. Samples were submitted to PEI Analytical Labs for analysis.

Fixed wing (Paradigm Precision Agriculture Services) and Quad Copter (Island Aerial Imagery) drone flights at eight sites captured digital and NDVI imagery on one or more occasions with some fields having three fly overs; others two.

N_2O emissions were collected from each treatment at five sites under a collaborative project with Dr. David Burton, Faculty of Agriculture at Dalhousie University. Gas sample collection commenced in mid-June and continued beyond crop harvest with equipment removed from all sites prior to onset of cold weather.

Figure 2: PEI potato planting operation

Prior to commercial harvest, six by fifteen foot sections of row, each containing the same number of plants, were hand harvested from each treatment at each site and placed in storage for subsequent grading and evaluation.

Post-harvest soil samples were collected at 0-6", 6-12" and 12-18" depths from each treatment in each field and submitted to PEI Analytical Labs for complete mineral and NO_3 analysis.

Two 4-6 oz tubers were collected from each sample and composites formed from each treatment. Samples were then submitted to the Soil Testing Lab for tuber nutrient content. All remaining tubers were delivered to Cavendish Farms Central Grading Facility for yield andquality analysis and establishment of gross crop values for each treatment.

3. Results

Crop Performance and Economics

Foliage in most Russet Burbank fields appeared similar to that observed in previous trials (Fig 3) in that plots which applied 4R Nutrient Stewardship had paler green foliage and less foliar canopy growth than the GSP treated areas. The nature of N application/timing in the area using 4R Nutrient Stewardship of the field may account for this occurrence in that the N is picked up in smaller amounts over a longer duration under 4R Nutrient Stewardship as opposed to the GSP program where the majority of the N is applied in the fertilizer bands at planting time. This change in intensity in color of foliage and overall plant growth was much less noticeable in the other varieties in the project (Fig4).

Major parameters presented in Table 1 include total yield in cwt/acre, % undersize, % oversize and % total defects by weight, tuber specific gravity (measurement of dry matter) and overall change in net crop value for all sites but AB&O.

Figure 3: 4R (left) and GSP (right) treated sections of Site I Russet Burbank

Figure 4: NDVI map — 4R (top) and GSP (bottom) — Site N

Per acre costs of implementing 4R Nutrient Stewardship vary depending on the individual growers' current fertilizer strategy. Any incremental (or reduced) costs associated with 4R Nutrient Stewardship applications have been accounted for and are reported as such in the Change in Net Crop Value column on a cost per acre basis. Generally, implementation of 4R Nutrient Stewardship ranged from $60 less - $50 more per acre. In several cases, reduced costs associated with lower rates of N and/or P_2O_5 have been offset by the increased cost in use of products such as KMag and Sulfate of Potash. Ultimately, readers should focus on the potential change in net crop value rather than any possible increase in cost per acre for the crops' fertilizer program.

Graphically (Fig 5), similar to 2013 and 2014 trials, most areas testing 4R Nutrient Stewardship applications produced crops with equal or better economic returns than the GSP sections. Although sites A, D, E and L produced numerically less economical value (no significant difference at p=0.05 or p=0.10), remaining sites produced crops with equal or better values. Crops using 4R Nutrient Stewardship at Sites F, G, H, I & N all had statistically higher (p=0.05) net crop values than the

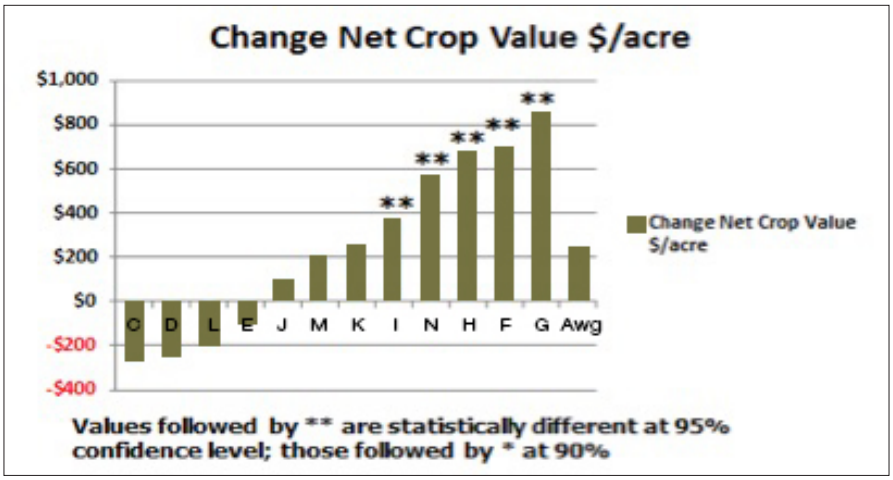

Figure 5: Effect of 4R Nutrient Stewardship fertilizer program on change in net crop value of PEI potatoes — 2015 4R Demonstration Trials

Table 1: Effect of 4R fertilizer program on tuber yield, quality and change in economic value of PEI potatoes — PEI4R Trials 2015

Site	Variety	Treatment	Total Yield cwt/acre	% Smalls	% 10 oz	% Total Defects	Specific Gravity	Net Change Crop Value $/acre
C	Superior	GSP	313**	6	26	7	1.077	
		4R	283	8	21	9	1.082**	-264
D	Prospect	GSP	430	2	54	8	1.076	
		4R	408	2	48	5	1.073	-241
E	Monticello	GSP	295	5	na	na	1.089	
		4R	408	2	na	na	1.088	-92
F	Prospect	GSP	296	4	33	8	1.085	
		4R	363**	3	18	1	1.083	690**
G	Russet Burbank	GSP	317	31	4	2	1.084**	
		4R	376**	17	12	2	1.081	843**
H	Russet Burbank	GSP	278	28	15	21	1.074	
		4R	337**	24	13	9	1.08	669**
I	Prospect	GSP	332	3	36	1	1.08	
		4R	365**	3	28	2	1.085*	365**
J	Russet Burbank	GSP	421	13	10	3	1.082	
		4R	410	10	14	6	1.081	86
K	Russet Burbank	GSP	342	10	27	46	1.085	
		4R	349	8	32	5	1.09*	244
L	Russet Burbank	GSP	419	5	45	2	1.085	
		4R	407	6	23	2	1.09	-195
M	GoldRush	GSP	272	7	34	4	1.07	
		4R	292	9	30	2	1.078	195
N	Ranger Russet	GSP	290	7	33	2	1.089	
		4R	317	6	38	2	1.094**	558**

Values followed by ** are statistically different at 95% confidence level; those followed by * at 90%

GSP treated areas. On average 4R Nutrient Stewardship strategies continue to produce an overall trend line improvement of approximately $200-300/acre in value when compared to all GSP programs.

Data from the two novel sites involving ESN/SRN (B,O) and one site where the fertilizer was not applied properly (A) are presented in Table 2. Data from these sites are presented separately due to the nature of the treatments (B,O currently experimental under PEI conditions; A due to fertilizer misapplication).

Significant differences were observed in crop foliage growth at Site B beginning at crop emergence and continuing for the duration of the growing season (Fig 6). This resulted in a large increase in yield for the area applying 4R Nutrient Stewardship and has resulted in numerous discussions with the cooperating grower as to possible reasons for the difference in crop performance.

Tuber yield and overall economic value from the similar fertility program at Site O resulted in a huge disadvantage for the 4R treated area. This seemed somewhat puzzling as late season aerial imagery (Fig 7), grower generated yield maps, post-harvest discussions with the cooperating grower and independent third party yield samples did not indicate 4R Nutrient Stewardship area was at a disadvantage to the GSP section.

Figure 6: 4R (left) and GSP (right) at site B — 2015 PEI 4R Nutrient Stewardship Demonstration Trials

Figure 7: 4R Nutrient Stewardship (right) and GSP (left) treated sections at Site O — 2015 PEI 4R Demonstration Trials

Table 2: Effect of 4R Nutrient Stewardship fertilizer program on tuber yield, quality and change in economic Value of PEI potatoes — Sites ACO — 2015 PEI 4R Demonstration Trials

Site	Variety	Treatment	Total Yield	%	%	%	Specific	Net Change Crop
			cwt/acre	Smalls	10 oz	Total Defects	Gravity	Value $/acre
A	Superior	GSP	412**	8	20	5	1.076	
		4R	374	12	4	3	1.085**	74
B	Ranger Russet	GSP	252	37	5	1	1.1**	
		4R	354**	7	17	2	1.094	1430**
O	Russet Burbank	GSP	479**	4	49	1	1.091	
		4R	421	6	37	4	1.094	-741

Values followed by ** are statistically different at 95% confidence level; those followed by * at 90%

Although there was error in application of the 4R fertilizer prescription at site A (36 lbs less N; 70 lbs less K_2O), the net crop value produced from the 4R treatment was similar to that of the GSP. This was due mainly to a significant increase in tuber dry matter values, thus increasing the crop value at the processing facility.

The Environmental Aspect

Similar to previous years, there were no consistent differences noted between fertilizer programs. Indicators were used to assess the uptake of nutrients into the plants, as well as the residual nutrients in soil after harvest. At some sites, the Nitrogen levels in petioles were lower in the areas applying 4R Nutrient Stewardship, indicating less nutrient uptake. This may help explain the lighter green foliage and smaller plant canopy observed at several sites. At other sites, petiole and whole plant nitrogen values were variable between the 4R and GSP practices.

Aside from tuber dry matter values (results similar to specific gravity values from Cavendish Farms Grading Facility), no other major differences were observed in the tuber analysis data. Major nutrient content in the harvested tubers was similar, regardless of the fertilizer program.

Nutrient balance sheet data are presented in Table 3. This data represents values of total N – P_2O_5 – K_2O applied, total amounts removed in harvested tubers and total amounts left in the field that may have the potential to pose risk if lost to the environment. Similar to past years, there was no consistent change in tuber nutrient status evident from the tuber lab analysis.

Nitrogen and phosphorous values are used for discussion purposes here; potassium is normally not associated with environmental issues in agriculture. Growers may choose to strive to improve overall soil potassium levels in their potato fields providing they choose the right source and the right application method.

Ten of the thirteen 4R Nutrient Stewardship samples submitted had less N and P_2O_5 on the balance sheet than the corresponding GSP samples. Two had higher N and one had higher P2O5. Values for both were considered equal for one N sample and two P_2O_5 samples.

The 4R Nutrient Stewardship research in PEI has shown that potato crops remove 90-140 lbs of N per acre in most cases based on present day yield values. Interestingly enough, it would require yields much higher to remove the excess N from the balance sheet for many of the GSP treated fields in this study.

Using the 4R principles to balance nutrient input and uptake by potato crops in PEI is part of an ongoing research effort in PEI. A healthy, high-yielding crop increases both the economic value and reduces the residual nutrients that could contribute to environmental concerns.

Phosphorous efficiency seems to be more difficult to predict. All sites applying 4R Nutrient Stewardship feature application rates of 10-30% less P_2O_5 and have not appeared to be the cause of any loss in economic value. It is important to remember however, that 4R Nutrient Stewardship is a systems-based approach that involves numerous plant nutrients and becomes difficult to evaluate the effect of change of any individual plant nutrient in particular.

Changes in post-harvest soil NO_3–N levels to a depth of 18" are presented in Fig 8. Fields applying 4R Nutrient Stewardship had lower NO_3–N levels at 11 of 15 locations. Four 4R Nutrient Stewardship sites had higher levels, two of these quite extreme (133 and

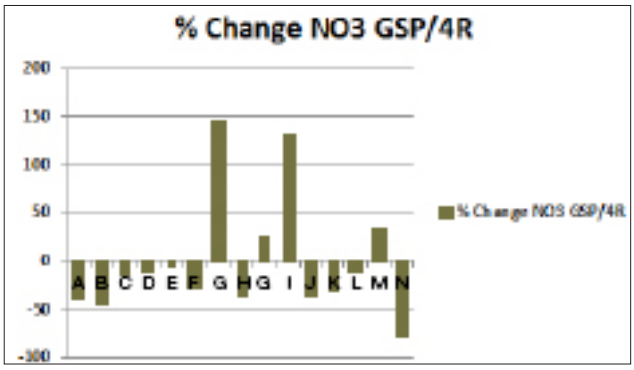

Figure 8: Percent change in post-harvest residual soil NO3 level at 18" depth - 2015 PEI 4R Demonstration Trials

Table 3: Nutrient balance sheet - 2015 PEI 4R Demonstration Trials

Site	Treatment	lbs added			lbs removed			lbs remaining		
		N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O
A	GSP	na	na	na	127	39	172	na	na	na
	4R	na	na	na	129	41	168	na	na	na
B	GSP	153	144	264	88	39	126	65	105	138
	4R	175	136	152	131	41	178	44	95	26
C	GSP	161	170	180	113	25	115	48	145	65
	4R	89	150	216	104	25	98	15	125	118
D	GSP	131	139	199	141	25	198	10	114	1
	4R	140	150	202	123	24	208	17	126	6
E	GSP	120	180	180	na	na	na	na	na	na
	4R	140	110	152	na	na	na	na	na	na
F	GSP	128	128	210	106	32	143	22	96	67
	4R	177	126	167	127	41	179	50	85	12
G	GSP	197	124	209	75	25	144	122	99	65
	4R	181	135	259	121	32	178	60	103	81
H	GSP	186	180	246	85	23	139	101	157	107
	4R	190	144	186	101	27	162	89	117	24
I	GSP	130	150	150	111	20	169	19	130	19
	4R	134	118	78	134	22	180	0	96	102
J	GSP	207	176	296	118	32	188	89	144	108
	4R	182	148	229	126	32	202	56	116	27
K	GSP	190	160	248	128	34	151	62	126	97
	4R	187	148	252	129	27	162	58	121	90
L	GSP	184	180	291	128	41	184	56	139	107
	4R	168	148	242	140	39	186	28	109	56
M	GSP	200	150	210	127	34	130	73	116	80
	4R	171	69	136	93	27	132	78	42	4
N	GSP	174	180	240	101	20	146	73	160	94
	4R	143	147	131	117	37	160	26	110	29
O	GSP	190	151	120	158	44	197	32	107	77
	4R	182	130	80	161	53	178	21	77	98

144%, respectively). These latter sites will be resampled in spring 2016 to confirm the difference. Overall, 4R Nutrient Stewardship soils had lower residual NO_3–N levels than the sites fertilized using conventional grower practices. Some N remains in the field in the crop debris of both treatments, however this source of N should not be considered an immediate risk to the environment while it remains in an organic form.

Greenhouse gas emissions (CO_2, N_2O, CH_4) were measured weekly using static vented chambers at four locations within each N treatment on six of the trial sites. Due to high spatial variability there were no significant ($p \leq 0.05$) differences in N_2O emissions as a result of N fertility treatment. Soil N_2O emissions tended to be somewhat higher from five of the six 4R Nutrient Stewardship treated sections in fields measured (BKLNO; Table 4). Note that two of these sites (B,O) involved the novel fertility program with foliar applied liquid N. Residual Soil NO_3 was lower at four of the five sites. This is the first year these observations have been included in the 4R Nutrient Stewardship trials and discussions amongst project stakeholders indicate that changes may be implemented for subsequent project activities.

Table 4: Cumulative nitrous oxide emission (kg N/ha) over the 2015 growing season.

Site	GSP	4R
	Cumulative N_2O Emissions (kg N ha^{-1})	
R1	1.6	4.5
R2	3.1	2.0
R3	2.1	3.6
R4	1.0	1.5
R5	1.8	3.4
Mean	1.7	3.2

4. Conclusions

Data presented in this report continue to support the use of 4R Nutrient Stewardship concepts for producing potatoes in Prince Edward Island. Applicable trials conducted at multiple sites (2013-2015 growing seasons) have demonstrated that introduction of subtle changes to the way the crop is fertilized can produce crops with at least as much economic value (Note – the goal here is to eventually increase economic value on a consistent basis) as the current level of management while lessening potential environmental risk.

The on-field economic benefit of implementing 4R practices on potato crop trials demonstrated a net economic gain of over $200 per acre relative to general standard practices.

On the majority of the 4R demonstration plots, 4R practices reduced the post-harvest residual soil nitrates level, reducing the risk of nitrate leaching into groundwater.

The 4R Demonstration farms located across PEI bring together the key stakeholders in nutrient stewardship. Grower workshops, demonstration farm tours and panel discussions foster increased awareness and education on the benefits of 4R Nutrients Stewardship and show how Canadian agriculture is growing sustainably.

5. Acknowledgements

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- All growers – MacLennan Properties, Jeff & Jason Smallman, Linkletter Farms, Oyster Cove Farms, Spring Valley Farms, Island Holdings, Willard Waugh & Sons, R&L Farms, Country View Farms, Martin Visser & Sons, Harold Godfrey & Son, Brian & Scott Annear, Rollo Bay Holdings, and Mo'Dhaicd'h Farms
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