Environmental Impact Assessment of Seed Sensing Technology by Bluefield Seeding Solution

Summary

Conventional planting technology often results in significant environmental losses of nitrogen (N) due to gaps where no plants can utilize the applied fertilizer. In contrast, seed sensing technology optimizes fertilizer use by increasing plant density per acre, improving crop nitrogen uptake, and reducing both nitrous oxide (N_2O) emissions and nutrient leachate losses compared to conventional methods. A review-based comparative analysis showed that seed sensing technology resulted in 421.7 fewer gaps per acre than conventional technology, which equates to approximately 47.5 acres (19.22 hectares) of the area on a 1,000-acre farm. The applied N range 135-208 kg/ha was selected for this theoretical analysis to cover the different N requirements of various potato varieties, resulting in 2595-3998 kg of N for the 19.22 ha gapped area. A range of 20 to 77% for N uptake/recovery by the plant was used to perform calculations. Several factors influence plant nitrogen uptake and nutrient use efficiency, including soil type, moisture content, rainfall, weather conditions, fertilization timing, and crop variety.

It is approximated that with the seed sensing technology, there is a potential that plants will recover between 519-3078 kg of N from the 19.22 ha area based on the soil type, fertilizer application time, mineralization, and environmental conditions. However, with conventional technology, all the applied N (2595-3998 kg) in the gapped area (where seed got missed) will be lost to the environment as N_2O into the atmosphere, nitrate leachate, or runoff, as no plant will exist to utilize the applied N. In the case of conventional technology, 1% (26-40 kg) of the initially applied N (2595-3998 kg) is expected to be emitted into the atmosphere in the form of N_2O. Given the high global warming potential of N_2O (273 times that of CO_2), these N_2O emissions are equivalent to 7084-10914 kg of CO_2. In contrast, with seed sensing technology, the N_2O emissions will be lower, with 1% of the remaining available N (80-33% of the applied N) converted into N_2O, equating to 1638-8736 kg of CO_2. A range of 15-40% was selected for calculating the N leaching losses based on an extensive literature search. This range covers factors influencing the leaching losses, such as soil type, field slope, and others. Using conventional technology, the leaching losses are expected to be 385-1583 kg. In contrast, seed sensing technology reduces leaching losses to 89-1266 kg by ensuring the presence of plants through precise seed placement. This literature-based analysis (1,000-acre farm) showed that the seed sensing technology has a great potential for lower environmental impact in N_2O emissions and leaching.

Literature Review

Nitrogen used by potato crops is critical because potatoes require high amounts of N for optimal growth and yield. However, managing N efficiently is essential to improve the plant's N uptake and minimize environmental impacts such as greenhouse gas emissions and nitrate leaching. The number of plants in an area, along with soil type, fertilizer application rate, and timing significantly influence N use efficiency throughout the crop growing season. Excess N not absorbed by the potato plants can leach into groundwater as nitrate, leading to groundwater contamination, or be released into the atmosphere as N_2O, a potent greenhouse gas. Potato crops mainly obtain N from N-based fertilizers, with additional sources including manure and soil mineralization. The required N rate for most growing potato varieties is shown in Table 1. The base value for the N rate ranges from 135 to 208 kg N/ha.

Table 1: Base values for different potato varieties (Adapted from Zebarth et al., 2007).

Variety Base Value	**kg N/ha (lb N/ac)**
Russet Burbank	208 (185)
Shepody	180 (160)
Russet Norkotah*	200 (180)
Superior	190 (170)
Snowden	200 (180)
Goldrush	190 (170)
Early table	135 (120)
Other mid-season	160-180 (140-160)
Other late season	180-200 (160-180)
Other low N requirement	135-160 (120-140)
*For standard clone, reduce value for new clonal selections	

Another study showed that the average N fertilizer rate for different potato varieties in Eastern Canada ranges from 25.42 to 82.90 kg N/ha, with an average of 61.45, and in the Atlantic, 76.48 kg N/ha (Table 2). This rate is applied in three growth stages: pre-plant, emergence, and tuber initiation. The estimated N uptake for potato crops was approximately 154.29 kg N/ha in the Canadian agroecosystem in 2016 (Karimi et al., 2020).

Table 2: Areas of seeded agriculture land in Canada and N fertilizer use by region or province in 2016 (Adapted from Karimi et al., 2020; Statistic Canada 2016, 2019).

Geography	Cropped land[a]	Summer fallow land	Tame or seeded pasture Million ha	Natural land for pasture	All agricultural land[b]	Fertilizer use Gg[d] N	Average rate[c] kg N ha^{-1}
Atlantic	0.42	0.00	0.04	0.05	0.97	35	76.48
Quebec	1.87	0.00	0.11	0.11	3.28	156	78.90
Ontario	3.65	0.01	0.21	0.32	4.99	214	55.46
Manitoba	4.67	0.04	0.38	1.37	7.14	418	82.90
Saskatchewan	16.39	0.58	1.95	4.56	24.92	1038	56.62
Alberta	10.22	0.26	2.19	6.42	20.34	675	54.36
British Columbia	0.58	0.01	0.21	1.43	2.59	20	25.42
Total or average	**37.79**	**0.89**	**5.08**	**14.26**	**64.23**	**2556**	**61.45**

[a] Cropped land refers to seeded area.
[b] All agricultural land = cropped land + summer fallow land + tame or seeded pasture + natural land for pasture + area in Christmas trees + woodlands and wetlands + other agricultural land.
[c] Average rate of fertilizer (kg ha^{-1}) = N applied/(area of cropped land + tame/seeded pasture).
[d] 1000 Gg = 1 Tg.

Potato is an N fertilizer-intensive crop, and plants acquire only 40–50% of the total applied N, and the remaining N is lost in the environment (Trehan & Singh, 2013). The effect of N fertilizer timing was measured on N use efficiency at tuber bulking and harvest. It showed that when N fertilizer was applied 75 kg/ha at the pre-plant, emergence, and tuber initiation stages, N fertilizer use efficiency ranged from 10.2% to 61.9%. At the same time, it ranged from 41.0% to 44.7% for the whole plant period at the tuber bulking and harvest stages. Studies with N applied close to planting report 30–60 % N use efficiency. However, these studies applied 100 % of the N supply at planting (Rens et al., 2016). Nitrogen recovery by the potato plant is more likely to occur with a lower N rate and low with a high N rate. For example, at the application rate of 100 kg N/ha, N recovery reaches 95%, and at 200 kg N/ha, it ranges between 20 to 75%, and it reduces to 60% with an increase in the application of 300 kg N/ha. The average N recovery was 53% for N applications between 101 and 200 kg/ha (Milroy et al., 2019). N uptake in potatoes applied with treatments of different N fertilizer rates (0, 60, 120, 150, 180, 210, and 240 kg N/ha) varied from 18.0 to 69.1 kg N/ha (Table 3), which equates to approximately 29 to 50% N uptake (Liu et al., 2021).

Table 3: Nitrogen uptake in potatoes applied with treatments of different N fertilizer rates. Different letters indicate significant differences (P < 0.05) among treatments in the same year. (Adapted from Liu et al., 2021).

Treatments	Nitrogen uptake (kg ha^{-1})	
	2017	2018
N0	18.6 ± 3.58d	18.0 ± 3.04d
N60	30.0 ± 6.15c	31.8 ± 7.86c
N120	37.2 ± 5.71b	35.7 ± 5.03c
N150	39.9 ± 3.72b	43.7 ± 3.81b
N180	45.4 ± 6.06b	53.7 ± 4.04ab
N210	44.9 ± 1.79b	52.3 ± 4.56ab
N240	62.7 ± 5.42a	69.1 ± 5.06a

According to a study, the total N from different N sources (fertilizer, atmospheric deposition, and mineralization) in a potato field over a year was 232 kg/ha, with the crop N uptake of 138 kg/ha, or 59% of the total N (Table 4). Soil type also influences plant N use efficiency. Crop N uptake is primarily low in sandy soil, as mostly applied N loss is due to leaching. Estimated N recovery throughout the potato plant in Eastern Canada ranges from 21 to 77% based on the soil type, loamy to sandy (He et al., 2012).

Table 4: Nitrogen balance for a potato field for one year (Adapted from Jensen et al., 1994).

N Inputs	
Fertilizer[1]	115
Atmospheric deposition	18
Net mineralization[2]	99
Total	232
N outputs	
Crop uptake[3]	138
Volatilization	13
Denitrification	0
Leaching	79
Total	230

[1]Mineral fertilizer plus mineral N supplied in pig slurry.
[2]Net N mineralization from soil organic matter, manure and crop residues.
[3]Uptake on a whole plant basis.

All the above studies showed that the optimal fertilizer N rate for a potato crop varies depending on the field, the year, and the specific crop variety, as each has different N demands. Crop N uptake depends on many factors, such as fertilizer rate, application time, growth stages, soil type, mineralization, environmental conditions, irrigation, and crop rotation. Based on the above literature review, the applied N range (135-208 kg/ha) is selected for the calculation as this range covers the N rate requirement for most potato varieties. For the calculation, the 20 to 77% range for N uptake/recovery by the plant is selected as this range covers all the factors that influence the crop N uptake efficiency.

Environmental Losses

Excess N not absorbed by the plants is released into the atmosphere as N_2O and lost to groundwater as nitrate leachate.

Nitrous Oxide (N_2O) Emissions

One percent of the available N not absorbed by plants is converted into N_2O, which then enters the atmosphere (Hergoualc'h et al., 2021; IPCC, 2006; IPCC, 2019). The global warming potential of N_2O is 273 times of CO_2, a factor used to convert N_2O emissions into CO_2 equivalent.

Leachate

Leachate percentages for N fertilizer in potato crops can vary based on soil type, field slope, rainfall, irrigation practices, soil management, fertilizer rate, type, and timing. Leaching losses can be significant in sandy soil under irrigation and heavy rainfall conditions. A study on irrigated potato production in Hubbard loamy sand soil showed 31 to 37% leaching loss for different N rates (34, 168, 252, and 336 kg N/ha) (Souza et al., 2019). Field slope also impacts the leaching loss. Bos, M (2021) found that N leaching losses were 47.70 kg N/ha (15%) from the flat slope, 58.52 kg N/ha (21%) from the medium slope, and 54.52 kg N/ha (22%) from a steep slope of Prince Edward Island. Annual nitrate leaching increases with an increase in N concentration, which is more significant for a two-year potato rotation than a three-year rotation. Annual average leaching predicted 36-40% in a two-year rotation and 28-33% in a three-year rotation system (Jiang et al., 2012).

Based on the above studies, 15-40% of the available N is selected to calculate the N leaching losses. This range considered the sandy loam soil type, flat to steep field slope, crop rotation, and different N rates.

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