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Different nitrogen fertilizer strategies to reduce nitrous oxide emissions on a potato rotation in a volcanic ash soil

Introduction

- ✓ Potato is the 4th most consumed crop in the world, and 3rd most relevant crop in Chile
- ✓ Potato yield has increased 50% in the last 50 years
- ✓ Of national production, 55% comes from rain-fed systems
- ✓ N rates used vary between 150-400 kg N ha⁻¹
- ✓ N fertilizer use accounts for 38% of total agriculture emissions in Chile (2022)
- ✓ There is a need to develop N management strategies to increase efficiency and reduce losses to the environment



Methodology

- ✓ 2016-2018
- ✓ Osorno soils series, Typic Hapludands
- ✓ Conventional tillage following 3-year pasture
- ✓ Potato-oat-potato-oat rotation
- ✓ Rain-fed
- ✓ Semi-automated GHG measurement system (5x5 m plots)
 - Acrylic, 50x50x15(50) cm
 - Two chamber basis per plot
 - 60 min deployment, 3 subsamples
 - Gas chromatography (He) ($11 \text{ ug N}_2\text{O-N m}^{-2} \text{ h}^{-1}$)
 - $n=3$, completely randomized block design

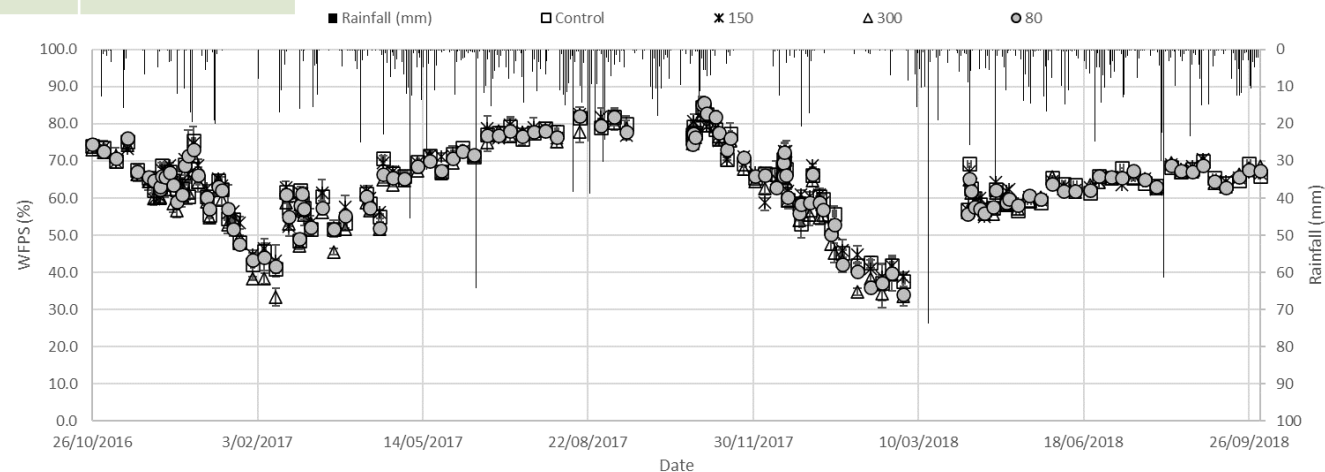


Methodology

| Treatments | Control | 300 | 150 | 80 |
|--|---|------------------------------|-----------------|------------------------------------|
| N rate, kg N ha ⁻¹ | 0 | 300 | 150 | 80 |
| Nitrogen source | - | Urea - granular | Urea - granular | Urea – granular, foliar spray |
| Fertilizer application | - | 30% planting 70% tubering | | 38% planting 61% tubering (2:1) |
| Basal fertilizer application (potato only) | 120 kg P ₂ O ₅ ha ⁻¹ (TSP, 46% P ₂ O ₅), 50 kg K ₂ O ha ⁻¹ (KCl, 62% K ₂ O), 20 kg S ha ⁻¹ (CaSO ₄ , 18% CaSO ₄) and 20 kg MgO ha ⁻¹ (MgO, 85% MgO) | | | |
| Potato (<i>Solanum tuberosum</i> L.) | Karú INIA (45-55 mm, 0.7m x 0.3m) October 2016 (March 2017), October 2017 (March 2018) | | | |
| Oat crop (<i>Avena sativa</i> L.) | Super Nova (120 kg ha ⁻¹) April 2017, March 2018 | | | |
| Measurements | Yield, soil available N, NUE, N ₂ O emissions, EF, EI | | | |

Air temperature (°C), rainfall (mm) and water field pore space (0-20 cm, %) during the experimental period. \pm SEM (n=3).

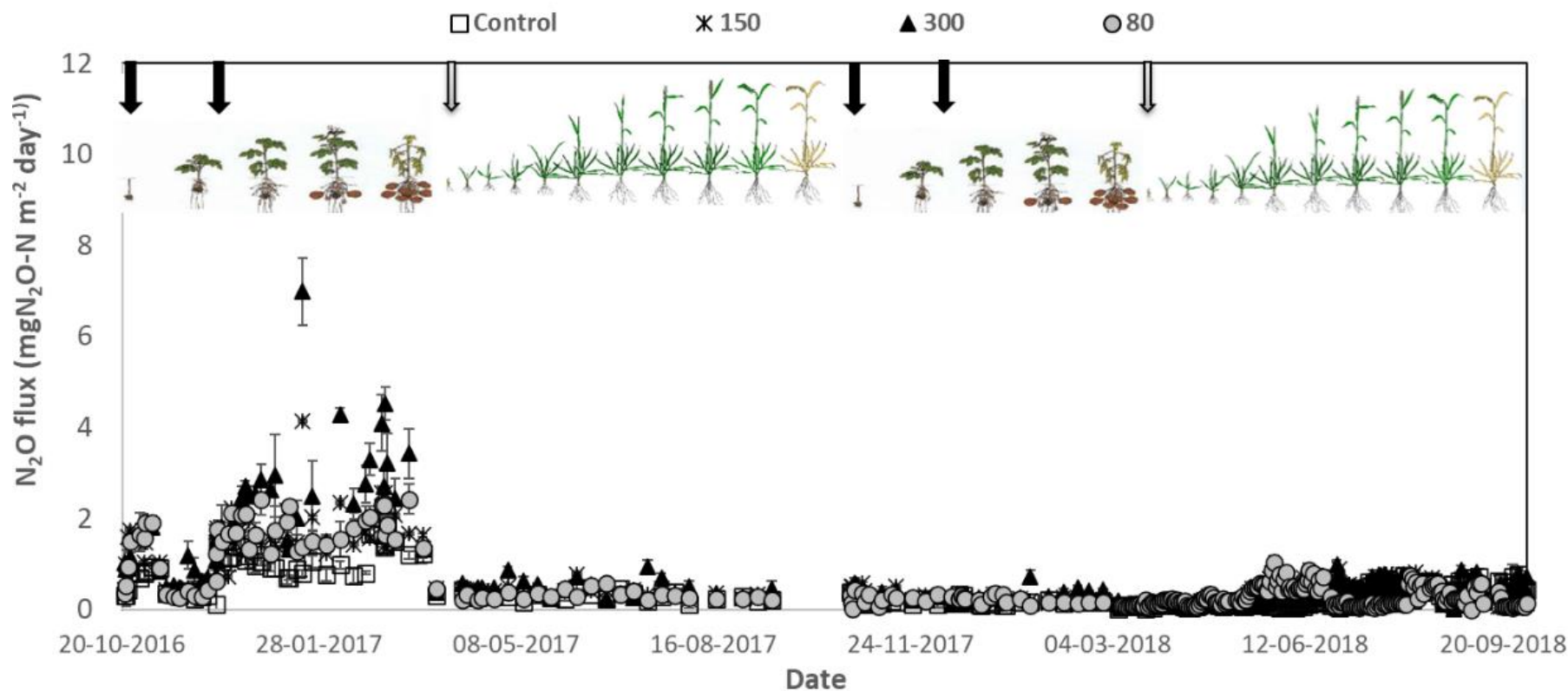
| | 2016/17 | 2017/18 |
|----------------------|---------|---------|
| Average T, °C | 11.2 | 10.7 |
| 39-year average, °C | 13.8 | |
| Average rainfall, mm | 1208.6 | 1117.3 |
| 39-year average, mm | 1253 | |
| WFPS, % | 54.1 | 52.9* |



Yield, N uptake and N use efficiency for each cropping season (n = 3, ± SEM)

| | | Nitrogen treatments (kg N ha ⁻¹ yr ⁻¹) | | | | Significance |
|------------------|------------------------|---|------------------------------|------------------------------|------------------------------|--------------|
| Season/Parameter | Unit | 0 | 150 | 300 | 80 | |
| 2016/17* | | | | | | |
| Potato yield | kg DM ha ⁻¹ | 8804.4 ± 646.1 ^b | 11299.2 ± 1056 ^a | 11883.1 ± 783.1 ^a | 12705.1 ± 881.7 ^a | * |
| Oat yield | kg DM ha ⁻¹ | 2019.9 ± 198.1 | 2405.4 ± 223.6 | 2297.8 ± 166.0 | 2330.4 ± 173.9 | NS |
| N uptake | kg N ha ⁻¹ | 150.2 ± 22.1 ^b | 219.6 ± 11.6 ^a | 241.6 ± 31.0 ^a | 226.2 ± 26.8 ^a | * |
| NUE | % | - | 46.2 ± 21.9 ^b | 30.5 ± 9.02 ^b | 94.9 ± 57.5 ^a | * |
| 2017/18 | | | | | | |
| Potato yield | kg DM ha ⁻¹ | 5098.5 ± 535.9 | 6126.0 ± 135.8 | 6298.4 ± 329.5 | 4856.0 ± 291.3 | NS |
| Oat yield | kg DM ha ⁻¹ | 1938.4 ± 32.6 | 2073.2 ± 218.8 | 1949.6 ± 121.2 | 2002.4 ± 118.9 | NS |
| N uptake | kg N ha ⁻¹ | 109.9 ± 12.9 ^b | 136.8 ± 16.3 ^a | 173.4 ± 15.3 ^a | 140.5 ± 1.7 ^a | * |
| NUE | % | - | 38.2 ± 14.4 | 21.1 ± 7.1 | 38.2 ± 14.4 | NS |
| Overall | | | | | | |
| Yield | kg DM ha ⁻¹ | 8930.6 ± 874.3 ^b | 10951.9 ± 620.1 ^a | 11214.4 ± 682.5 ^a | 10946.9 ± 692.6 ^a | * |
| N uptake | kg N ha ⁻¹ | 147.3 ± 21.0 ^b | 218.7 ± 18.3 ^a | 238.2 ± 15.0 ^a | 222.6 ± 16.6 ^a | * |
| NUE | % | - | 47.6 ± 12.7 ^b | 30.3 ± 5.5 ^b | 94.2 ± 31.3 ^a | * |

Flux of N_2O ($\text{mg N-N}_2\text{O m}^2 \text{ d}^{-1}$) per treatment ($n=3, \pm \text{SEM}$)



Black arrows: N fertilizer application (30% and 70% for the first and second arrow, respectively).
Grey arrows: date of the oat cover crop seeding. No N fertilizer was applied to the cover crop

Emissions of N-N₂O, EF and EI (n=3, ±SEM)

| | | N rate applied (kg N ha ⁻¹ yr ⁻¹) | | | | Significance |
|------------------------------------|--|--|--------------------------|--------------------------|---------------------------|--------------|
| Season/Parameter | Unit | 0 | 150 | 300 | 80 | |
| 2016/17* | | | | | | |
| N ₂ O emissions, potato | kg N ₂ O-N ha ⁻¹ | 1.5 ± 0.03 ^c | 2.2 ± 0.08 ^b | 3.2 ± 0.26 ^a | 2.1 ± 0.04 ^b | * |
| N ₂ O emissions, oat | kg N ₂ O-N ha ⁻¹ | 0.4 ± 0.03 | 0.6 ± 0.02 | 0.7 ± 0.01 | 0.5 ± 0.05 | NS |
| Emission Factor | % | - | 0.62 ± 0.08 | 0.72 ± 0.09 | 0.87 ± 0.15 | NS |
| Emission Intensity | kg N ₂ O-N t DM ⁻¹ | 0.19 ± 0.01 ^b | 0.22 ± 0.02 ^b | 0.29 ± 0.01 ^a | 0.18 ± 0.02 ^b | * |
| 2017/18 | | | | | | |
| N ₂ O emissions, potato | kg N ₂ O-N ha ⁻¹ | 0.2 ± 0.01 | 0.3 ± 0.06 | 0.4 ± 0.04 | 0.3 ± 0.02 | NS |
| N ₂ O emissions, oat | kg N ₂ O-N ha ⁻¹ | 0.5 ± 0.01 | 0.7 ± 0.01 | 0.7 ± 0.01 | 0.6 ± 0.01 | NS |
| Emission Factor | % | - | 0.16 ± 0.05 | 0.16 ± 0.03 | 0.09 ± 0.03 | NS |
| Emission Intensity | kg N ₂ O-N t DM ⁻¹ | 0.12 ± 0.01 ^b | 0.13 ± 0.01 ^b | 0.16 ± 0.02 ^a | 0.13 ± 0.003 ^b | * |
| Overall | | | | | | |
| N ₂ O emissions | kg N ₂ O-N ha ⁻¹ | 1.4 ± 0.01 ^c | 2.0 ± 0.09 ^b | 2.7 ± 0.17 ^a | 1.8 ± 0.07 ^{bc} | *** |
| Emission Factor | % | - | 0.39 ± 0.06 | 0.44 ± 0.06 | 0.48 ± 0.09 | NS |
| Emission Intensity | kg N ₂ O-N t DM ⁻¹ | 0.15 ± 0.01 ^b | 0.17 ± 0.02 ^b | 0.22 ± 0.01 ^a | 0.16 ± 0.01 ^b | *** |

Conclusions

- ✓ Potato yield was similar +N treatments (average 39 t ha⁻¹, max 65 t ha⁻¹)
- ✓ The lack of yield response to N rate could be related to N soil dynamics
- ✓ Apparent NUE was greater in the lowest N rate treatment (94%) and increase with yield (3.6 times greater in the 2016/17 season)
- ✓ Cumulative N₂O emissions ranged between 0.6 (Control) to 2.1 kg N ha⁻¹ in the +N treatments. Higher N rates increased N₂O emissions and low N fertilization resulted in a significant reduction in N₂O emissions

Conclusions

- ✓ EFs were lower than the originally default IPCC value (2006 GL, 1%)
- ✓ N fertilizer rates used for potato production in Chile can be reduced significantly
- ✓ A N fertilizer application strategy considering granular and foliar application offered an opportunity to increase NUE, as well as for reducing N₂O emissions
- ✓ Rainfall availability during a cropping season is key to N fertilizer rate decision at farm level, as well as for the generation and adoption of country specific emissions factors



Thank you

Muchas gracias

Grazie mille