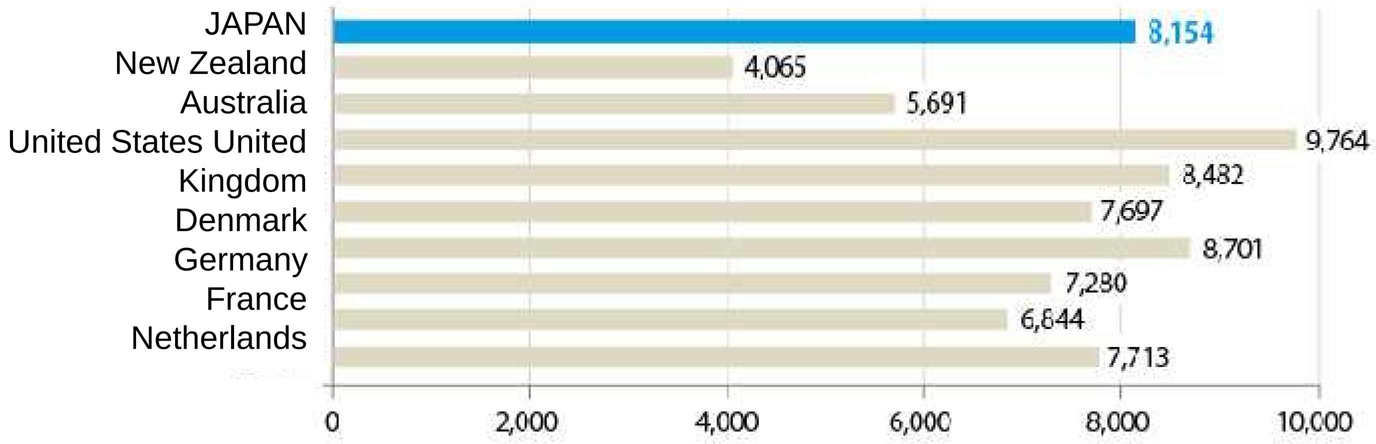
Dairy Cow Urine Sodium Content and Soil Aggregate Size Influence the Amount of Nitrogen Lost from Soil

Toru HAMAMOTO Yoshitaka UCHIDA
Hokkaido University, JAPAN

Hokkaido has the largest economic scale of dairy farming

- Cool summer and icy/snowy winter
- One fourth of Japan’s total arable land

Milk production per cow (kg milk) (2012)



Typical dairy farms in Hokkaido to keep high milk production

- Housed system
- Imported and concentrated feeds

Sodium (Na) contents in urine may be increased

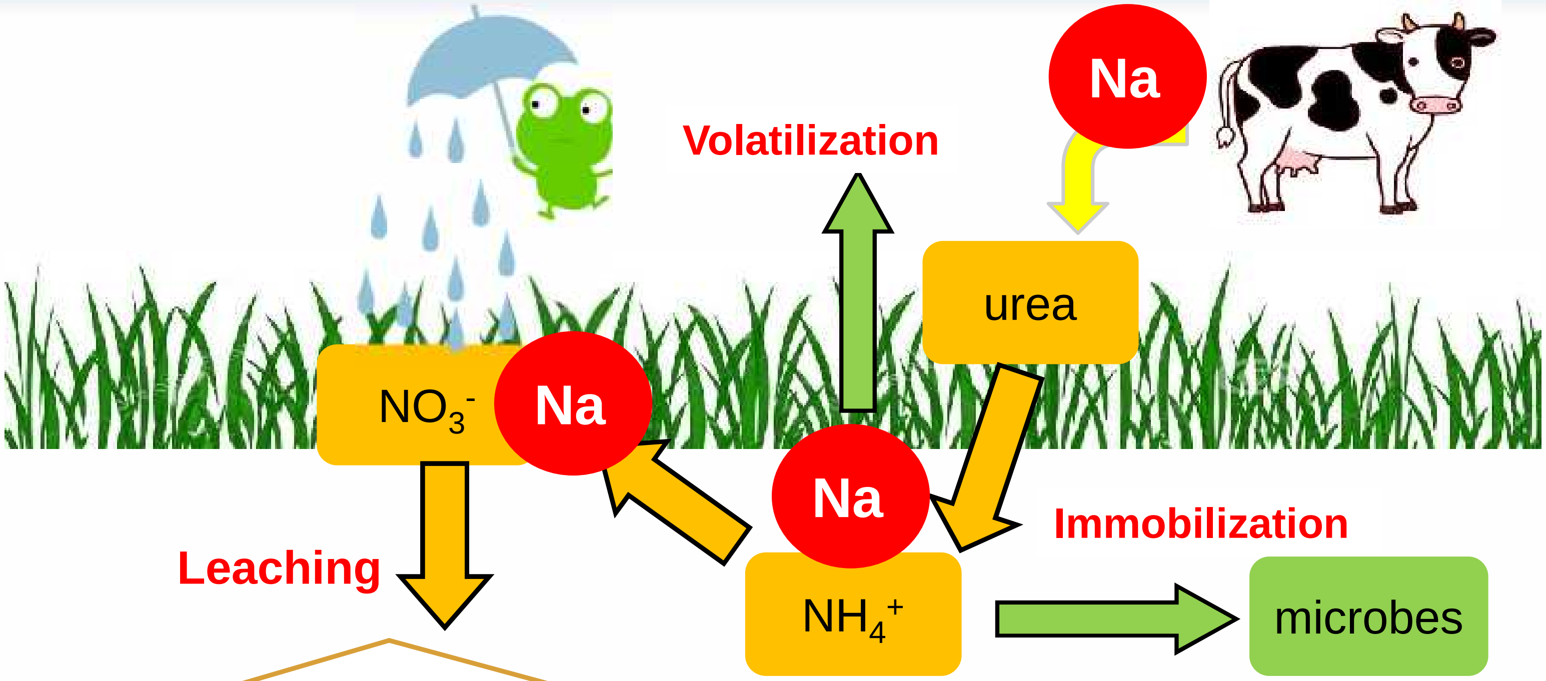
During summer (heat-stressed), increased Na intake promises high milk yield. (Schneider *et al*. 1988)

Na contents vary in cow urine (0.03-0.43%). (Kume *et al*. 2011)

Na^{+} in soils often negatively influences soil microbial processes. (Quanzhong and Guanhua 2009)

However, there is no study focused on
Na concentrations in urine and nutrient losses from soil.

Relationship with N and Na in urine on pasture soils

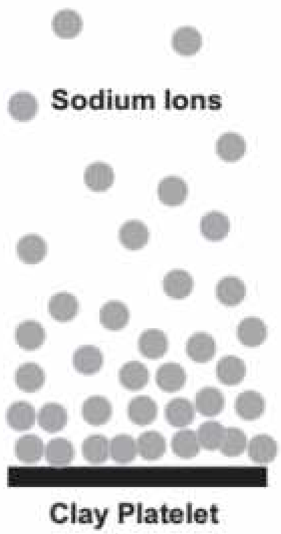


Nutrient loss and environmental pollution

•A major source of nutrient from dairy farming (Di and Cameron 2002)
•Eutrophication of aqueous environment (McGechan and Topp 2004)
•Health problems such as blue baby syndrome (Knobeloch *et al*. 2000)

The importance of aggregate structure in soils

Na contents in soils are known to degrade aggregate structure (sodicity).



Na^+ form layers of ions in clay platelet and result in swelling of the soil. (Hanson et al. 2006)

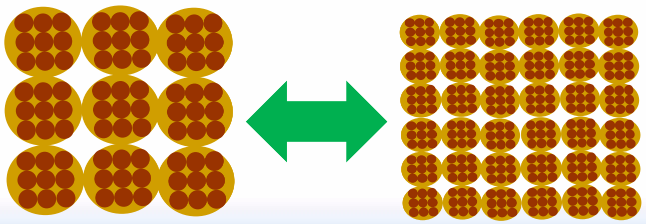
→ Na contents in urine may also have negative impacts on soils – low soil moisture, plant growth and microbial activity inhibition

Are there any relationships with urine Na contents and aggregate sizes?

The aim of this study

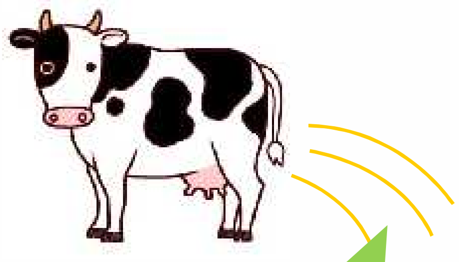
- **To research whether Na contents in urine affect soil nutrient dynamics**

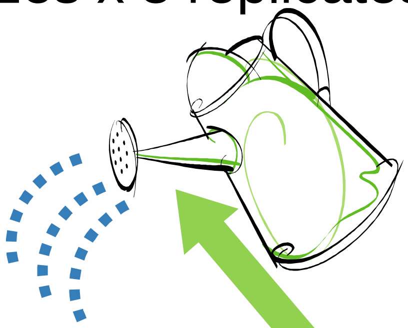
- **To investigate these impacts are different by changed aggregate size**


aggregate structure

Experimental set up (incubation experiment)

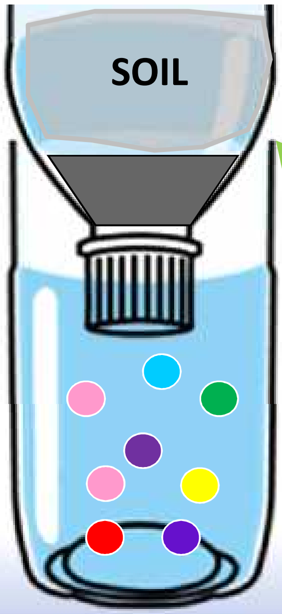
4 urine treatments x 3 aggregate sizes x 3 replicates = 36 pet bottles





Urine included 50kgN/ha.
NaCl added to adjust urine-Na content.

Urine treatment
Control (no urine and Na)
Urine (4.28 g Na / L)
Urine-Na (5.34 g Na / L)
Urine-NaNa (6.09 g Na / L)



Heavy rain treatment

2, 8, 14 days after the urine application, 30 mm of simulated rain was applied.

Leached $\mathbf{NO_3^-}$ and $\mathbf{NH_4^+}$ were measured.

Aggregate size
0-3 mm (small)
3-5 mm (medium)
5-7 mm (large)

Soil property and urine composition

	All values are in g N, Ca, K, or Na (L cow urine^{-1})			
	N	K	Na	Ca
Urine		5.02 + 0.09	4.28 + 0.02	0.004 + 0.00026
Urine_Na	2.26 + 0.17	6.02 + 0.30	5.34 + 0.11	0.003 + 0.00226
Urine_NaNa		5.75 + 0.12	6.09 + 0.03	0.009 + 0.00264

	Small	Medium	Large
pH	5.8 ± 0.1	5.8 ± 0.0	5.8 ± 0.0
NO_3^--N mg kg^{-1}	25.8 ± 0.8	23.6 ± 1.7	18.8 ± 1.4
NH_4^+-N mg kg^{-1}	15.2 ± 0.7	17.7 ± 0.6	13.8 ± 1.0
K mg kg^{-1}	539.3 ± 9.6	552.3 ± 7.0	555 ± 17.1
Ca mg kg^{-1}	6392 ± 90.5	6307 ± 133.4	6118 ± 275.3
CEC meq kg^{-1}	421.3 ± 11.7	422.3 ± 10.5	416.7 ± 2.1
Organic matter %	6.5 ± 0.3	5.4 ± 0.1	5.2 ± 0.4
Soil texture			
Sand %	13.7 ± 3.2	14.8 ± 3.5	18.4 ± 4.5
Silt %	56.7 ± 1.4	56.5 ± 6.5	51.8 ± 4.5
Clay %	29.5 ± 4.3	28.7 ± 3.3	29.8 ± 3.7

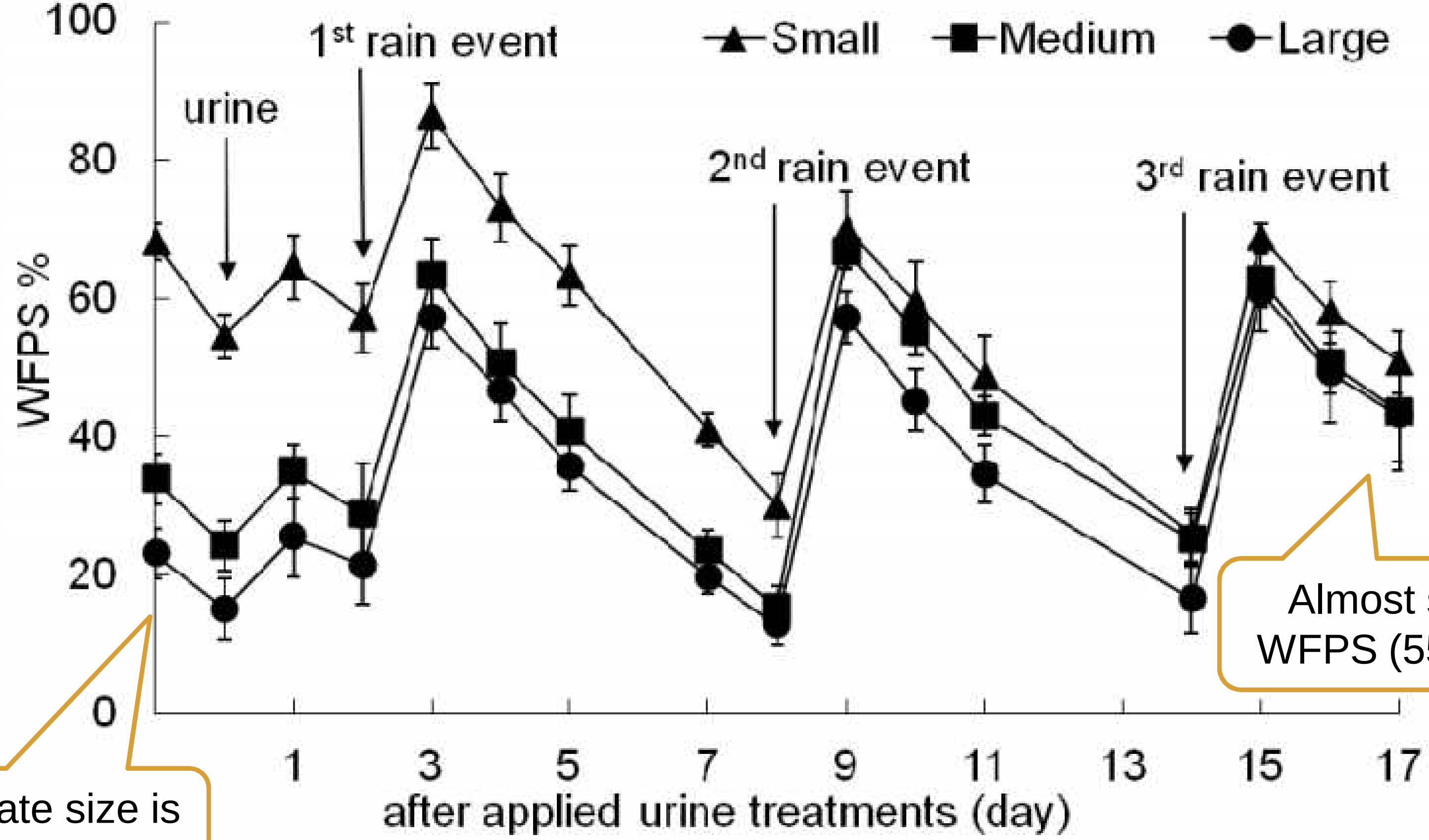
The soil used in the experiment was **Andosol** (volcanic) collected (0–5 cm depth) from a dairy farm pasture in Hokkadio University , JAPAN

Photos

Collect leachate

The soil surface area was 34 cm^2 and the soil depth was 2.5 cm (85 cm^3).

WFPS change during incubation

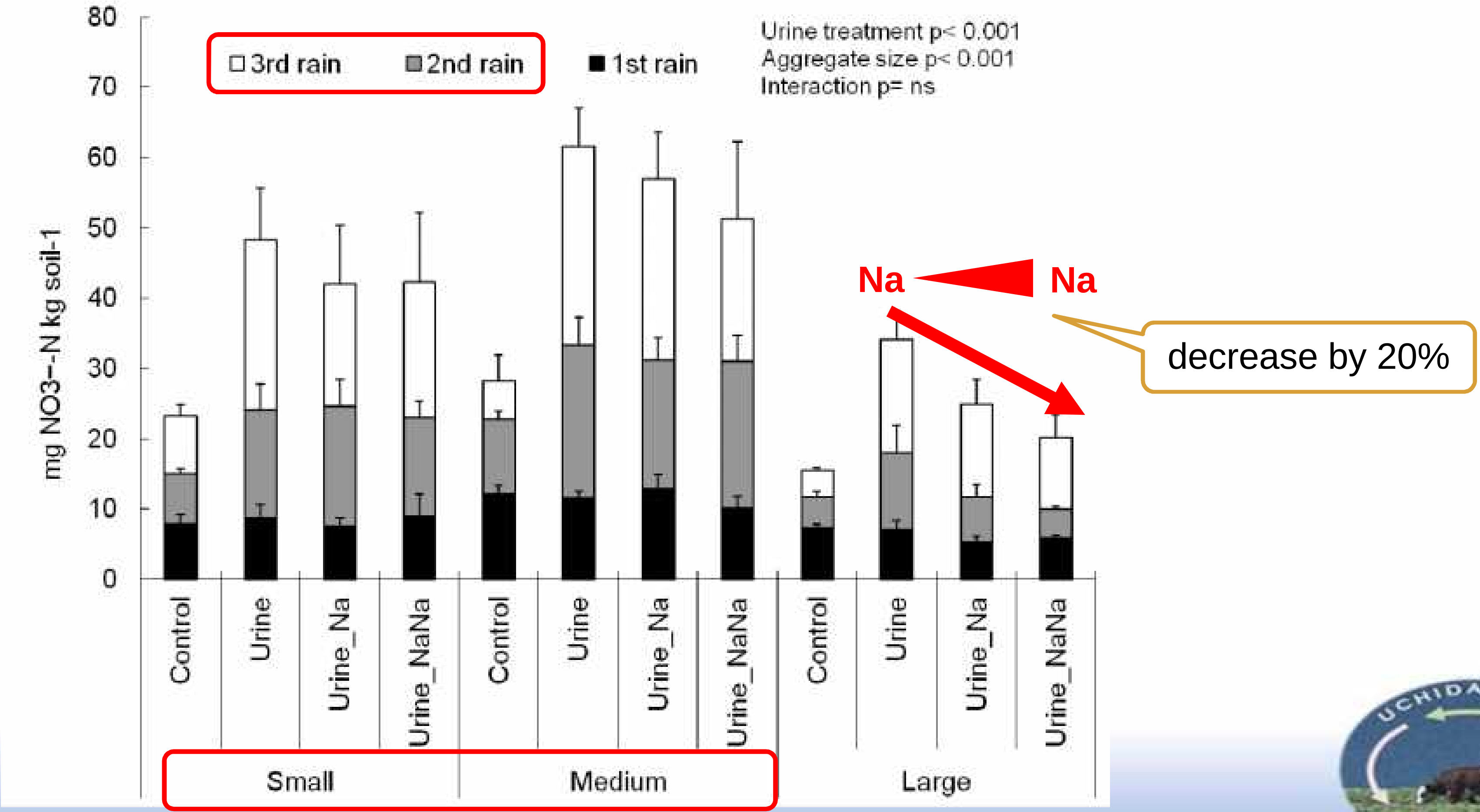


Small aggregate size is higher WFPS (70 %).

Almost same WFPS (55-60%)

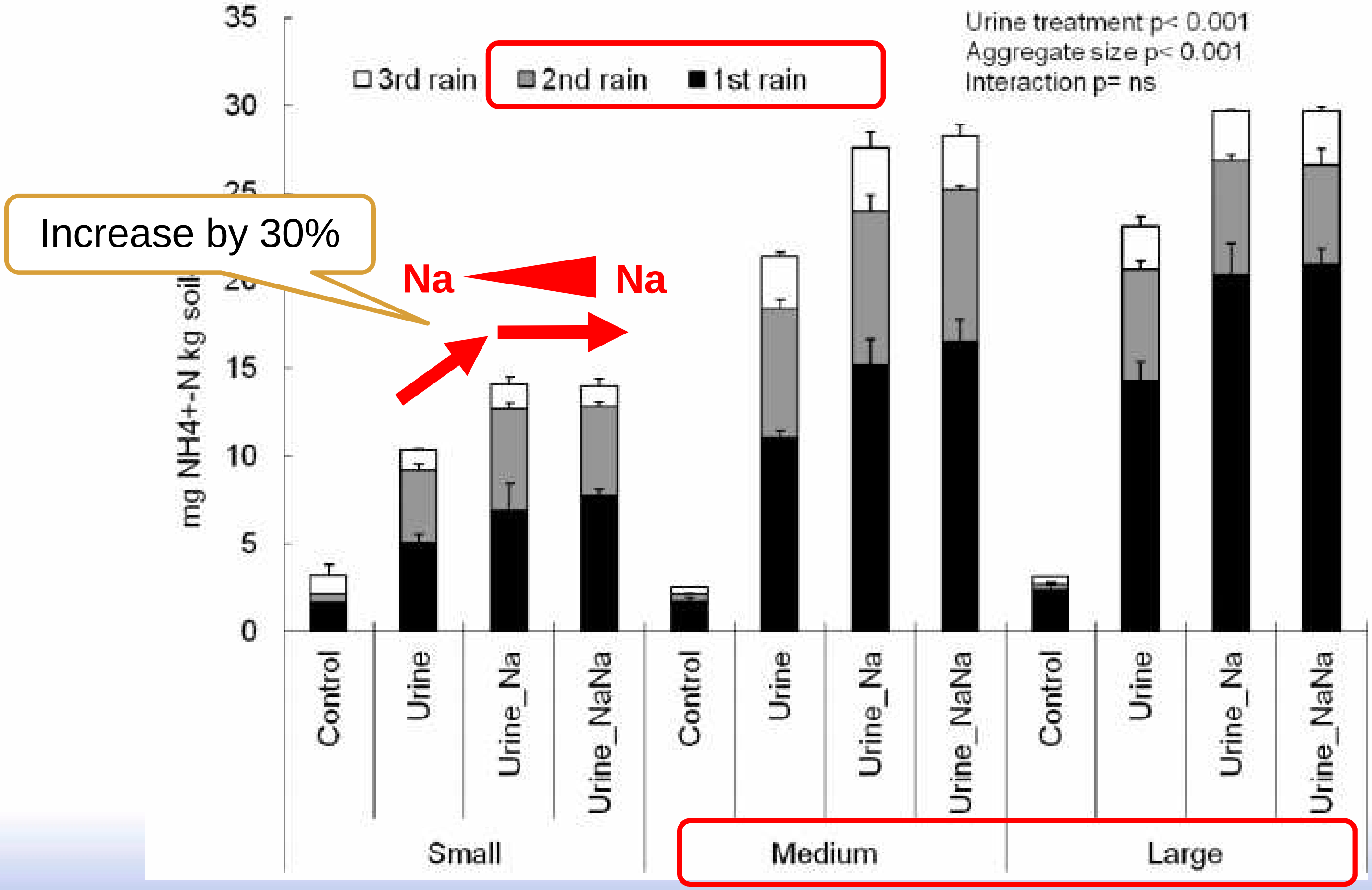
NO_3^--N loss after 3 rain events

NO_3^--N leachate decreased by adding Na

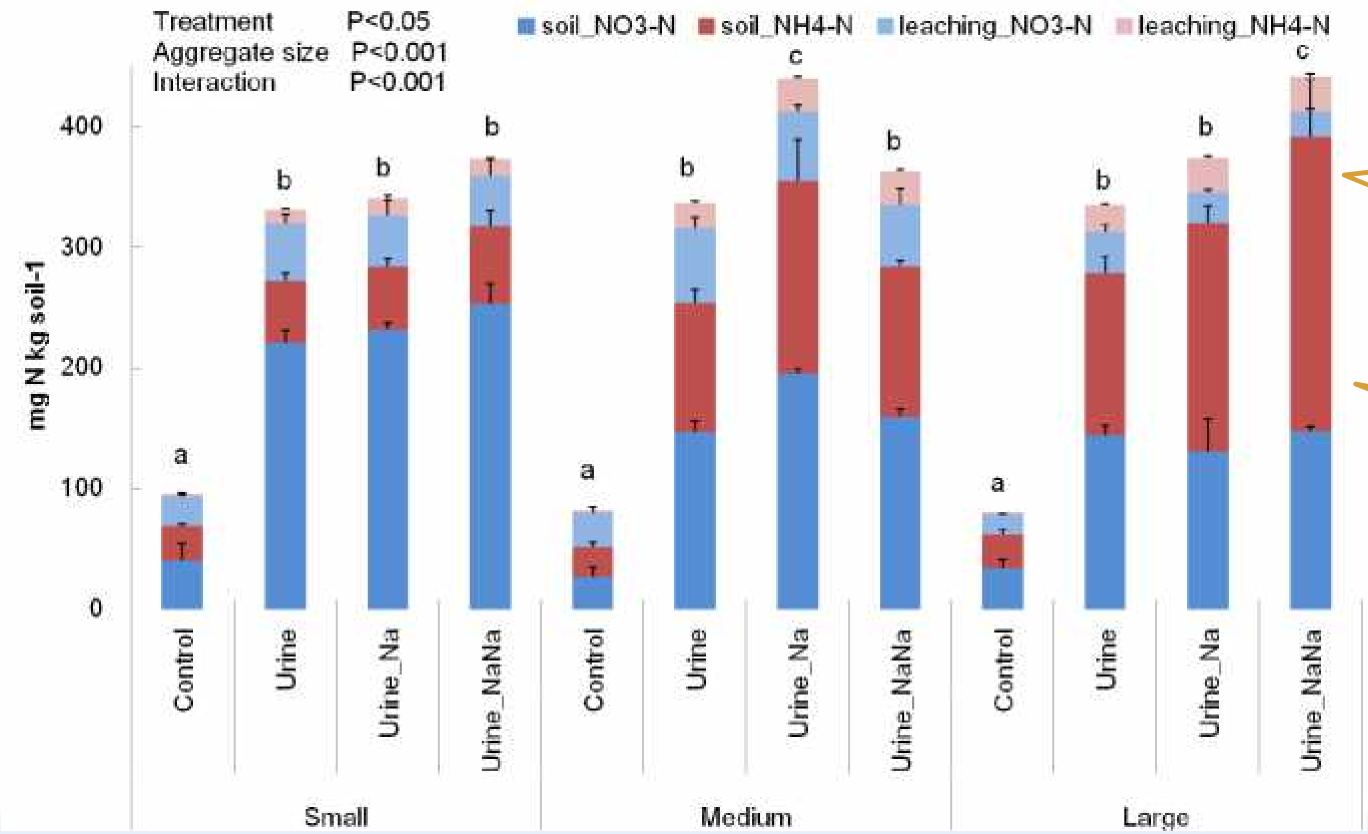


NH_4^+-N loss after 3 rain events

NH_4^+-N leachate increased by adding Na



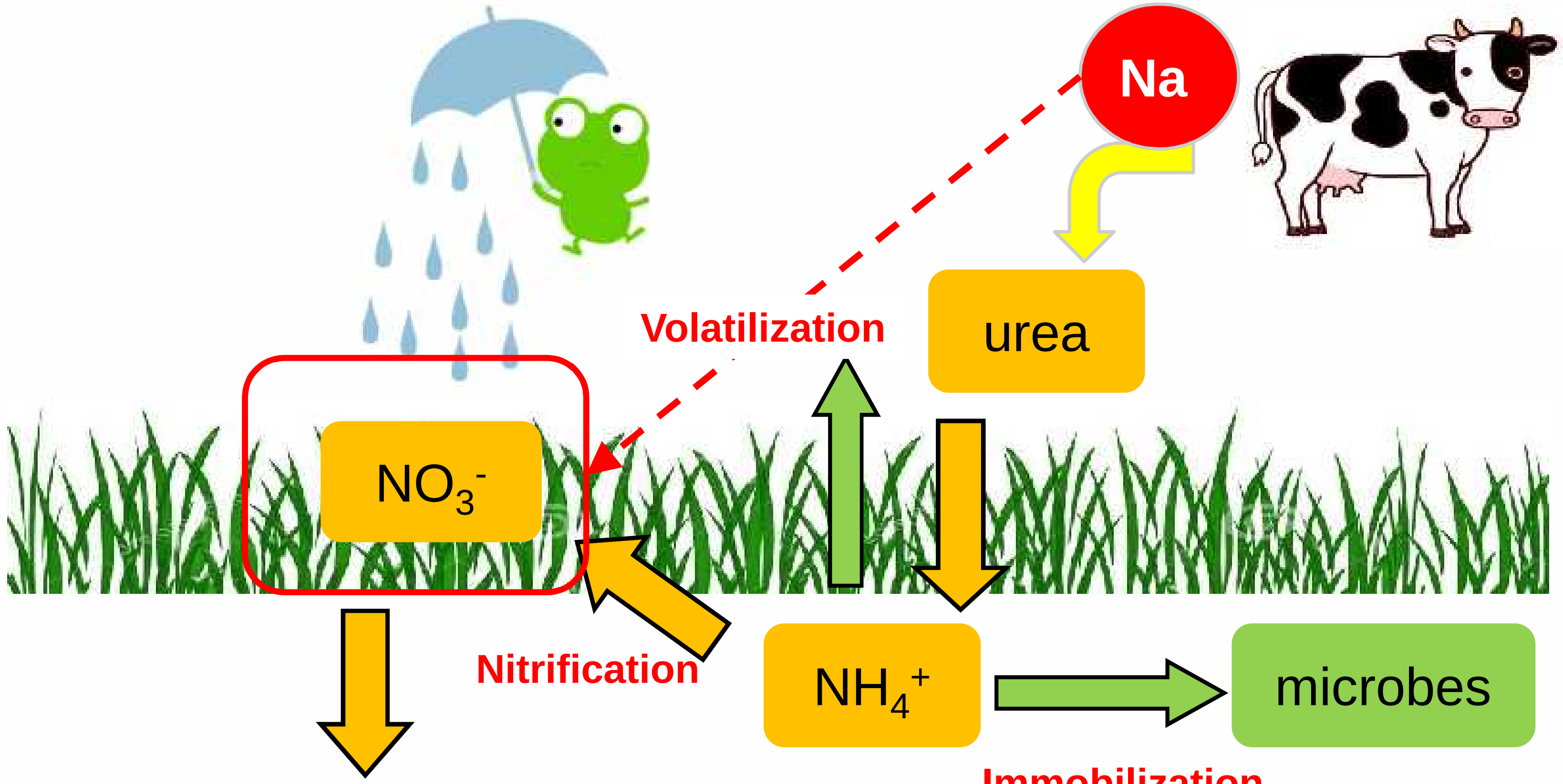
Increased urine-Na affects on the amount of inorganic-N (leachate + soil)



Adding Na increased Inorganic-N due to Immobilization or Volatilization.

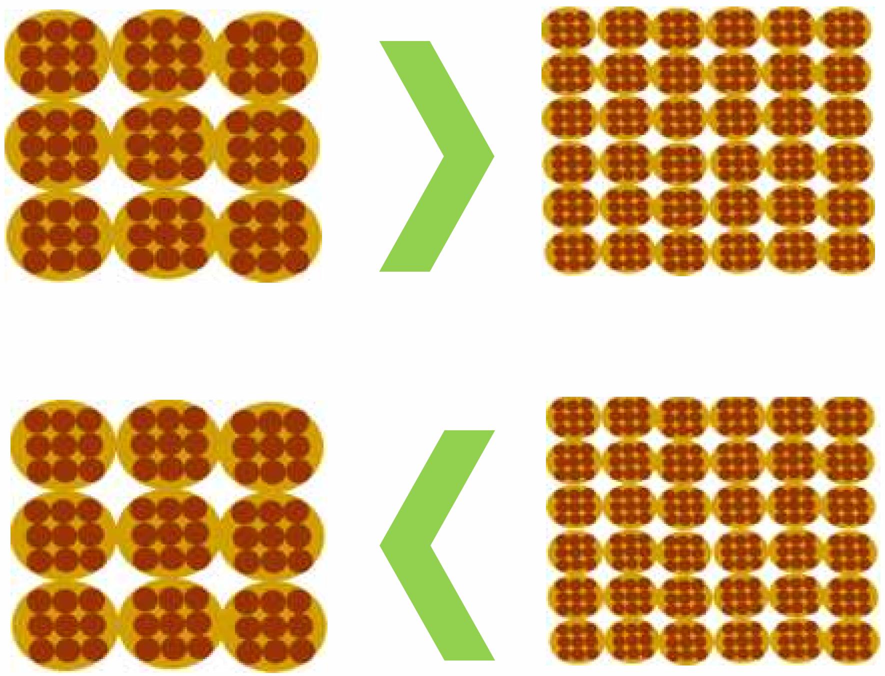
Remaining N in soils were changed by aggregate size.

Relationship with N and Na in urine on pasture soils



Relationship with aggregate sizes

Large (5-7cm) **Small (0-3cm)**

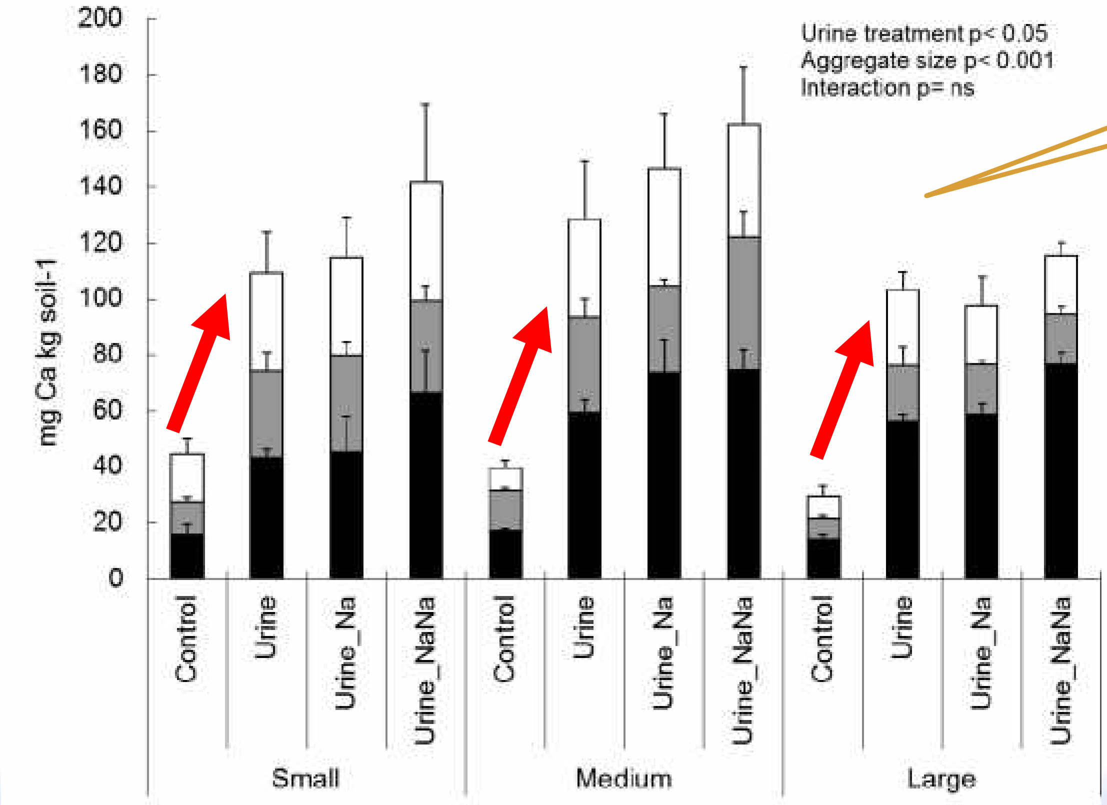


- **Na influence (low nitrification speed and accumulation of inorganic-N in soils) is high in larger aggregate.**

- **The amount of NO_3^--N loss from soils and in soils is high in smaller aggregates.**

Thank you

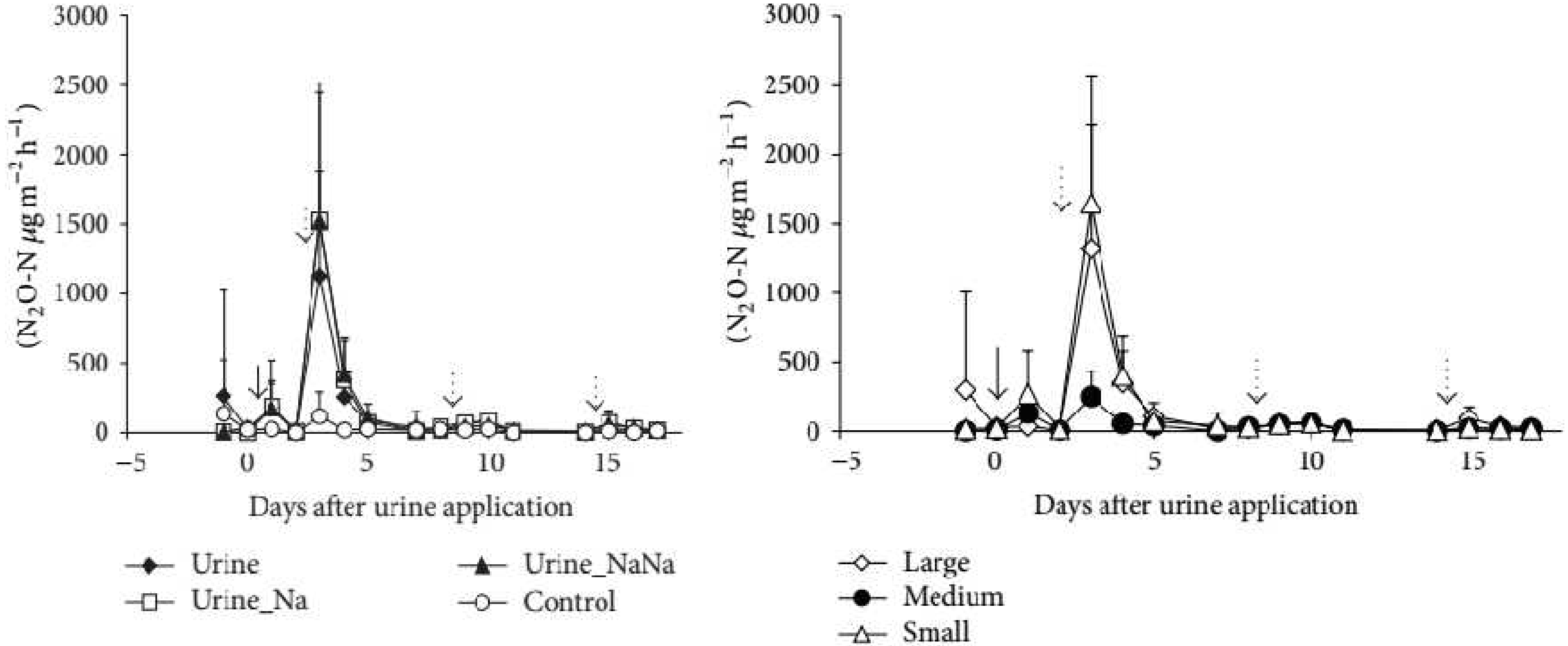
The loss of Ca^{2+} increased with added urine but no effect of urine-Na.

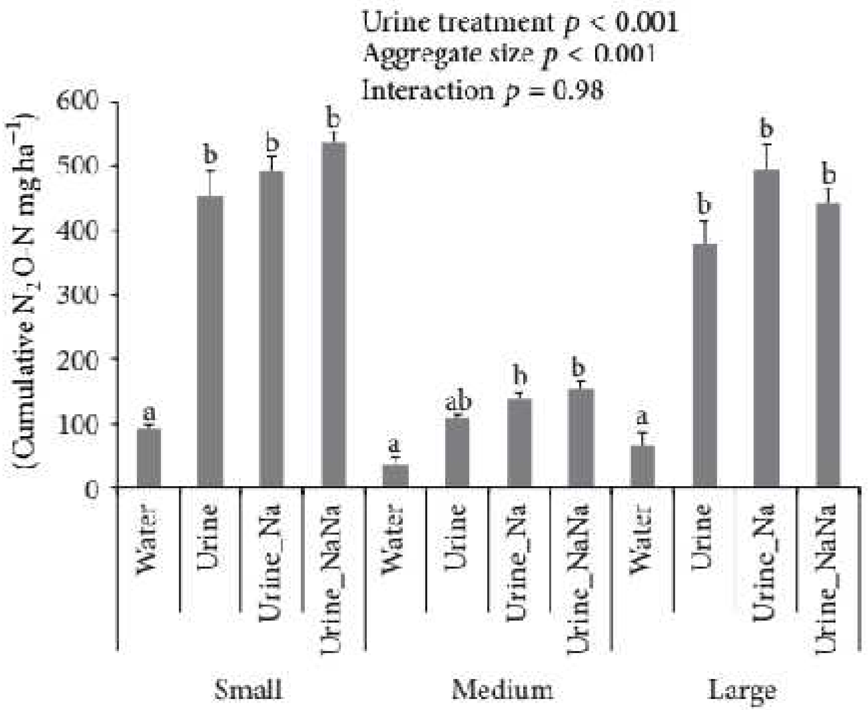


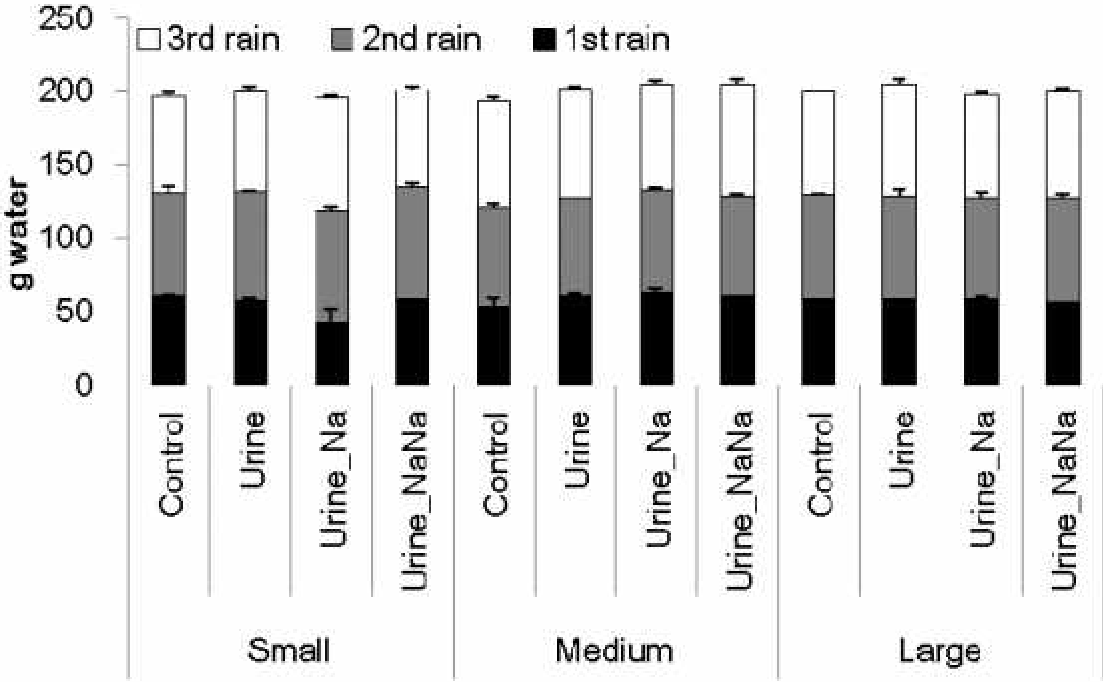
The urine-Ca was only 0.44 mg/kg soil

Ca^{2+} loss was likely to be occurred **due to the addition of K^+ and H^+ in urine** (Williams et al. 1989).

The e□ect of varying Na+ concentrations in urine on N2O emissions was not clear.




Urine treatment p < 0.001
Aggregate size p < 0.001
Interaction p = 0.98
(Cumulative N2O-N mg ha−1)
600
500
400
300
200
100
0
Water
Urine
Urine_Na
Urine_NaNa
Small
Medium
Large


3rd rain
2nd rain
1st rain
g water
250
200
150
100
50
0
Control
Urine
Urine_Na
Urine_NaNa
Small
Medium
Large

- Increased urine-Na contents **slowed nitrification**.
- Na contents in urine influenced on NH_3 volatilization or immobilization?
- Need to discuss the influence of Cl^-
- Negative ions, nitrate ions and chloride ions are is not adsorbed, sulfate ion is adsorbed to some extent → pH and Cl^- is no relationship.

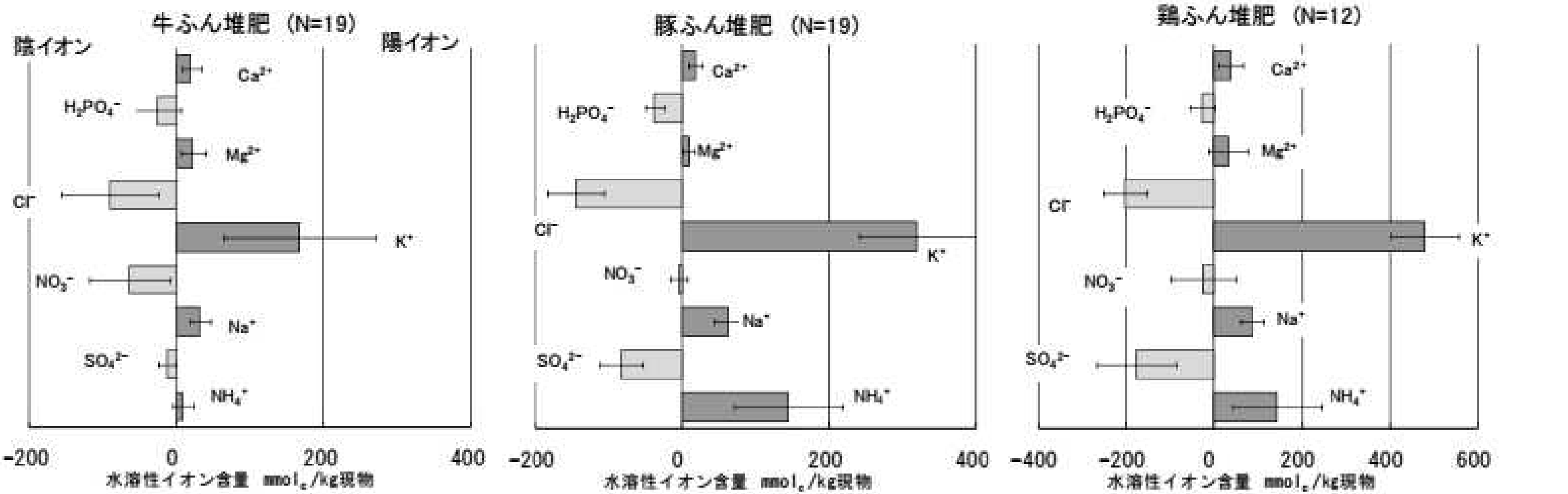


図１　各家畜ふん堆肥中の塩類組成

large amount of Cl^- ions are included in manure.
Negative ions, nitrate ions and chloride ions are is not adsorbed, sulfate ion is adsorbed to some extent→pH and Cl^- is no relationship.

Ammonium was added as either NH_4Cl or $(NH_4)_2SO_4$ salt solutions with four osmotic potential levels ranging from −96 to −692 and −90 to −669 kPa, respectively. Osmotic potential gradients were obtained by adding KCl to the NH_4Cl solutions and K_2SO_4 to the $(NH_4)_2SO_4$ solutions. At 0, 3, 9, 14, and 28 d, samples were extracted with 2 M KCl and analyzed for NH^+_4, NO^-_3, and NO^-_2. At 15 d, soil solutions were recovered by centrifugation and analyzed for Al, Ca, Mg, K, Na, Mn, NH_4, NO_3, PO_4, SO_4, Cl, pH, and osmotic potential. Soil solution osmotic potential was lower in soils amended with Cl^- than with SO^{2-}_4 salt solutions. In both soils, nitrification was inhibited by Cl^- and by decreasing soil solution osmotic potential. Chloride inhibition of nitrification was greatest ($\simeq$30%) at low soil pH (4.9-5.5) but disappeared or decreased markedly in magnitude above pH 6.0 to 6.2. Because of soil solution osmotic potential and pH by Cl^-interaction effects, inhibition of nitrification would be expected to be greatest where Cl-containing fertilizers are applied in a band on moderately acid (pH 5.0-5.5) soils.