Nitrification of Fertilizers

ammoniacal fertilizers used in study on the rate nitrifying bacteria function at various ammonia concentrations in soils

F. E. Broadbent, K. B. Tyler, and G. N. Hill

Results of experiments with three ammonium fertilizers—aqua ammonia, ammonium sulfate, and ammonium nitrate—have shown that not only the rate of nitrification but also the elapsed time required before the maximum rate is attained depends on the ammonia level in the soil.

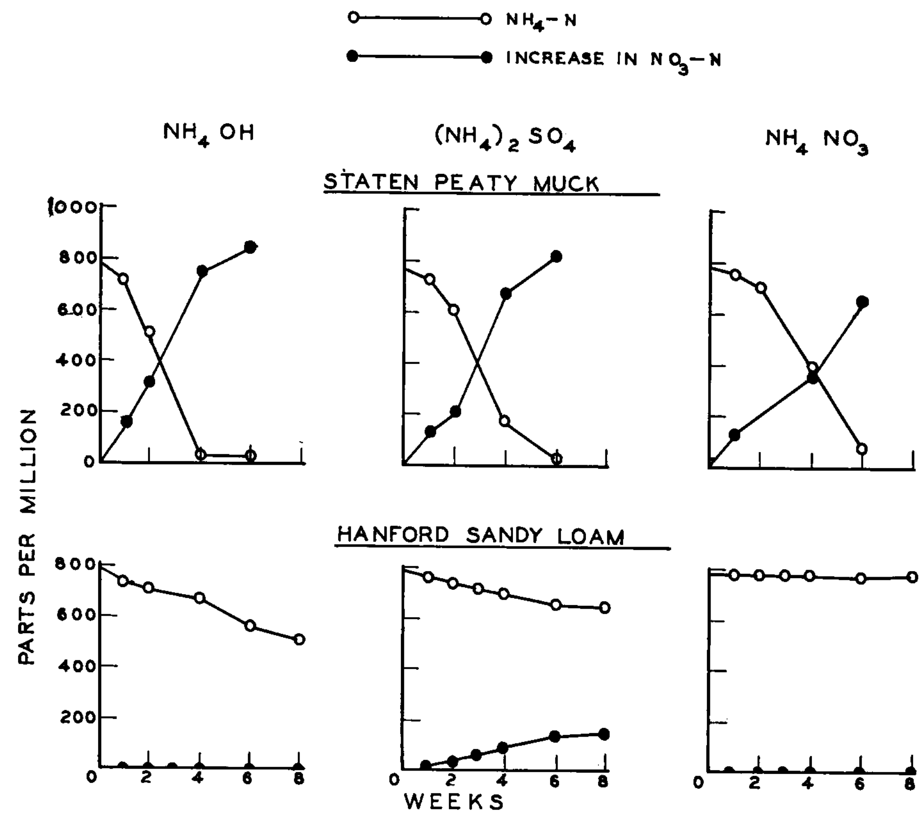
When ammoniacal fertilizers are applied to soils, the ammonium iron is usually retained on the soil colloids in a zone close to the point of initial contact. Therefore, band application results in very high localized concentrations of ammonia in soil. The zone in the immediate vicinity of a fertilizer band provides the environment in which the nitrifying bacteria must function. These bacteria obtain their energy from the conversion of ammonia to nitrate, and are active only where ammonia is present. The soil may also have a high hydrogen ion concentration where anhydrous ammonia or aqua ammonia is applied, because these materials make the soil temporarily more alkaline.

Although application rates of ammonia-nitrogen as high as 1,600 pounds per acre may seem excessive, even higher concentrations may be measured in the fertilizer band area at normal rates of field application. The high concentrations used in the studies were intended to simulate the local environment of nitrifying bacteria in the field.

Nitrification Rates as Influenced by Ammonia Concentration

Nitrogen source	Ammonia-N added lbs./acre	Yolo loam		Sacramento clay	
		Period of Max. rate weeks	Maximum rate lbs./acre/day	Period of Max. rate weeks	Maximum rate lbs./acre/day
Aqua ammonia	100	0–1	18	0–1	22
	200	0–1	26	0–1	22
	400	0–1	34	0–1	25
	800	0–1	38	0–1	29
	1600	2–3	35	0–1	29
Ammonium sulfate	100	0–1	14	0–1	18
	200	0–1	15	0–1	23
	400	3–4	20	2–3	22
	800	3–4	38	2–3	38
	1600	3–4	40	2–3	32
Ammonium nitrate	100	0–1	11	0–1	16
	200	0–1	15	1–2	16
	400	0–1	15	2–3	28
	800	0–1	15	2–4	18
	1600	3–4	8	6–8	24

Changes of ammonia and nitrate nitrogen in two soils receiving an application of 1,600 pounds nitrogen per acre.



In the soils which had an initial pH—relative alkalinity-acidity—reaction below pH 7, aqua ammonia nitrified the most rapidly, followed by ammonium sulfate and ammonium nitrate. Nitrifying bacteria prefer a slightly alkaline reaction, and the aqua ammonia temporarily raises the pH of acid soils, and provides a more suitable environment for the nitrifiers. In poorly buffered sandy soils anhydrous or aqua ammonia may raise the soil pH so high—near the center of the application zone—that nitrification is completely stopped for a time.

In Hanford sandy loam there was very little increase in nitrate during an 8-week period when 1,600 pounds ammonia-nitrogen per acre was present. The decrease in ammonia nitrogen where aqua ammonia was applied was due to volatilization loss rather than nitrification, since no increase in nitrate was observed.

In well-buffered Staten peaty muck ammonia nitrogen declined rapidly, with a corresponding increase of nitrate.

During nitrification, acid is formed by the conversion of ammonia to nitric acid which can result in localized pH changes of considerable magnitude.

The soil around nitrifying bacteria

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NITRIFICATION

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may become quite acid as the oxidation of ammonia progresses, and nitrification rate will decrease.

In two calcareous soils—Salinas clay and Imperial clay—nitrification of all three fertilizers proceeded rapidly at low levels of application. At higher levels part of the ammonia was converted to nitrite instead of being oxidized all the way to nitrate. The nitrification process takes place in two steps, each performed by a different group of bacteria. In the first step ammonia is converted to nitrite by *Nitrosomonas* and *Nitrosococcus*. In the second step nitrite is converted to nitrate by *Nitrobacter*. Free ammonia, present when soil pH is above 7, is toxic to *Nitrobacter*, so that nitrites may accumulate temporarily in alkaline soils at high ammonia concentrations. Nitrites are toxic to growing plants in relatively small amounts, but fortunately their toxicity is much less in alkaline soils than in an acid environment.

In the calcareous soils there were decreases in ammonia nitrogen not compensated by increases in nitrite and nitrate, indicating some loss of ammonia by volatilization.

These experiments indicate that although nitrification may be inhibited in localized zones due to high ammonia concentration, high pH, or other factors, nitrate production usually goes on at rapid rate. Slow nitrification in the field may occasionally be observed where biological activity in general is decreased by factors such as inadequate moisture or low temperature, but is not likely due to lack of a vigorous nitrifying population in the soil. For example, the maximum rate of nitrate production observed in the Salinas clay was 88 pounds nitrogen per acre per day.

pH Changes in Two Soils During Nitrification

Weeks									
0	1	2	3	4	0	1	2	3	4
Yolo loam					Hanford sandy loam				
100 pounds nitrogen (aqua)									
8.0	7.0	7.4	7.1	7.1	6.6	6.0	5.6	5.7	5.6
1,600 pounds nitrogen (aqua)									
9.9	8.5	7.8	6.7	5.8	9.8	9.1	9.1	9.1	9.1
100 pounds nitrogen (ammonium sulfate)									
7.4	6.9	6.8	6.8	6.8	6.1	5.7	5.3	5.5	5.8
1,600 pounds nitrogen (ammonium sulfate)									
7.1	6.4	6.0	6.0	5.4	5.9	5.9	5.5	5.2	4.9

F. E. Broadbent is Associate Professor of Soil Microbiology, University of California, Davis.

K. B. Tyler is Assistant Olericulturist, University of California, Riverside.

G. N. Hill is Laboratory Technician, University of California, Davis.

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ROOTSTOCKS

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barely visible, then moved to 36°F until planted on February 19.

In the 1957–58 studies, cuttings were made of Old Home, Farmingdale, and Variolosa pear, and of Brompton, White Damson, and Santa Rosa plum.

Old Home and Farmingdale are valuable pear root and body stocks due to their high resistance to fire blight—*Erwinia amylovora*. Variolosa is under test as a promising vigorous pear rootstock. White Damson and Brompton plums are being tested for use as peach rootstocks in wet areas in orchards. Limited experiments have indicated that Santa Rosa plum may have considerable resistance to oak root fungus so it is being tried as a rootstock mainly for Japanese plums.

Only fall-collected cuttings were included in the 1957–58 tests. Three replicate groups of 50 cuttings each were used for each treatment. One set of cuttings was planted in the nursery immediately after collecting on November 20. Most of the cuttings were treated by soaking their bases in a solution of indolebutyric acid for 24 hours at various concentrations. Untreated pear cuttings were not included because earlier studies showed complete failure to root unless IBA was used.

A second set of cuttings, also collected November 20, was treated with IBA then stored in slightly damp peat moss in orchard lug boxes at 65°F for four weeks to hasten initiation of root primordia. At the end of this time—December 20—when adventitious roots were barely visible on the cuttings they were removed and planted in the nursery.

A third set of cuttings was handled as the second except rather than planting in the nursery after the 65°F storage period, they were transferred to 40°F for 10 weeks until they were planted on March 3. The 40°F temperature prevented further root development and, at the same time, overcame the rest period of the buds.

The most suitable treatment varied with the variety. Old Home pear cuttings gave the best rooting when planted in the nursery just following the 65°F storage period. Variolosa pear showed best rooting when planted in the fall immediately after collecting. Farmingdale pear completely failed to root under any of the treatments. Brompton plum rooted best when planted in the fall just after collecting. White Damson and Santa Rosa plum both rooted best when given the 4-week 65°F storage period just before planting. Holding the cuttings at 40°F for 10 weeks following the 65°F storage period was detrimental with all the varieties used in the 1957–58 tests.

Root systems developed by August 7 on typical cuttings of the varieties used in the 1957–58 tests. *Left to right*—Brompton plum, White Damson plum, Santa Rosa plum, Old Home pear, and Variolosa pear.