THE EFFECTS OF SOIL FUMIGATION ON THE NITROGEN NUTRITION OF POTATOES

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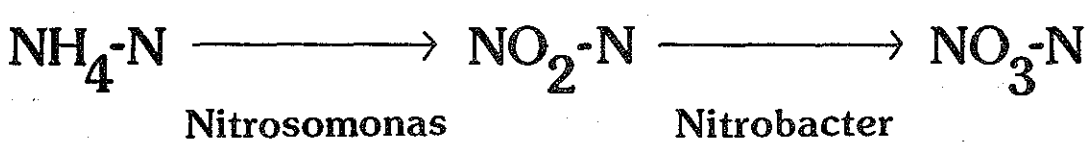
Soil fumigation is a common production practice used by many potato growers in the Pacific Northwest to control Verticillium wilt and plant pathogenic nematodes. The effect of fumigation, however, is not limited to reducing populations of pathogens but may also reduce populations of beneficial soil microorganisms. Many studies have shown that nitrifying bacteria in particular are sensitive to many soil fumigants, and as a result, a temporary inhibition of nitrification following fumigation may occur. This could be an important factor in the selection of nitrogen fertilizers to be used on fumigated soil.

Currently, ammonium nitrogen fertilizers are popular because they are relatively inexpensive and not leached from the soil as readily as nitrate nitrogen. In most agricultural soils applied ammonium is rapidly converted to nitrite and then nitrate by the nitrifying bacteria, Nitrosomonas and Nitrobacter (Fig. 1). If, however, populations of these bacteria are reduced the ammonium form of nitrogen will predominate in the soil. This can be beneficial in production of crops that prefer ammonium nitrogen. Although numerous studies have been conducted there is only limited evidence for the preferred form of nitrogen in potatoes.

Figure 1. Nitrification.



The objectives of this research were: (1) to determine the effects of soil fumigation on the response of potatoes to different nitrogen sources; and (2) to examine the effects of different nitrogen forms on the growth and development of potatoes.

In 1981 a preliminary field study was conducted to examine the effects of nitrogen form on potato production in fumigated soil. The fumigation treatments consisted of: (1) Telone C-17^{R} at the label recommended rate of 27 gal./acre; (2) Telone C-17^{R} at double the recommended rate of 54 gal./acre; and (3) a non-fumigated control. The two nitrogen treatments consisted of an ammonium source supplied as ammonium sulfate and an ammonium plus nitrate source provided by ammonium nitrate.

The final harvest data from this experiment showed that ammonium nitrate tended to provide higher total yields and higher yields of U. S. No. 1 tubers than ammonium sulfate in all three fumigation treatments (Table 1). Fumigation tended to reduce total yields, however, and significantly reduced the yield of U. S. No. 1 tubers compared to the non-fumigated control.

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Table 1. Effect of Telone C-17[R] and Nitrogen Source on Total Yield and Yield of U.S. No. 1 Tubers in 1981.

Nitrogen source	Telone C-17 (gal./acre) 0	27	54
	Total yield (cwt/acre)		
NH_4NO_3	533.5	397.0	475.5
$(NH_4)_2SO_4$	468.4	360.4	354.2
Mean	501.4	379.2	414.9
	U.S. No. 1 (cwt/acre)		
NH_4NO_3	202.5	127.6	135.6
$(NH_4)_2SO_4$	148.1	86.5	95.5
Mean	175.8	107.1	116.0

In 1982 field studies were conducted at two locations. One field plot was established on the WSU Othello Research Unit and the other on a farm near Quincy, Wa. The six fumigation treatments consisted of: (1) fall applied Telone C-17[R]; (2) spring applied Telone C-17[R]; (3) fall applied Vapam[R]; (4) spring applied Vapam[R]; (5) spring applied D-D[R]; and (6) a non-fumigated control. The two nitrogen treatments consisted of an ammonium source applied as aqua ammonia at time of planting and later supplemented with ammonium sulfate and a combination nitrogen source supplied as ammonium nitrate.

Nitrification studies were conducted on soil collected from the Othello plot. Although all fumigants altered populations of nitrifying bacteria, by time of planting all fumigated soil had nitrifying power similar to non-fumigated soil with the exception of the spring applied Vapam[R] treatment.

At the Othello planting the highest total yields were obtained with the fall and spring applied Vapam[R] treatments (Fig. 2). Nitrogen source did not significantly affect total yield regardless of fumigation treatment. The fall and spring applied Vapam[R] treatments also tended to provide more U.S. No. 1 tubers than the other fumigation treatments (data not shown). Nitrogen source had no effect on quality.

Conversely, nitrogen source had a significant effect on yield and quality of tubers at Quincy (Fig. 3 & 4). In general, fertilization with ammonium nitrogen resulted in higher total yields and more U.S. No. 1 tubers than fertilization with ammonium nitrate. Fumigation did not affect yield or quality of tubers at Quincy.

At the Othello location symptoms of Verticillium wilt were evident throughout the plot by mid-August. Plants growing in soil fumigated with Vapam[R], however, remained green longer regardless of nitrogen source. Plants in Vapam[R] treated soil were therefore capable

of continued tuber growth longer than plants in other fumigation treatments. There probably was no response to nitrogen source because there was no difference in nitrifying power between fumigation treatments. As a result of the nitrification process in the soil, even in plots fertilized with only ammonium nitrogen, plants took up a large portion of their nitrogen as nitrate.

Figure 2.

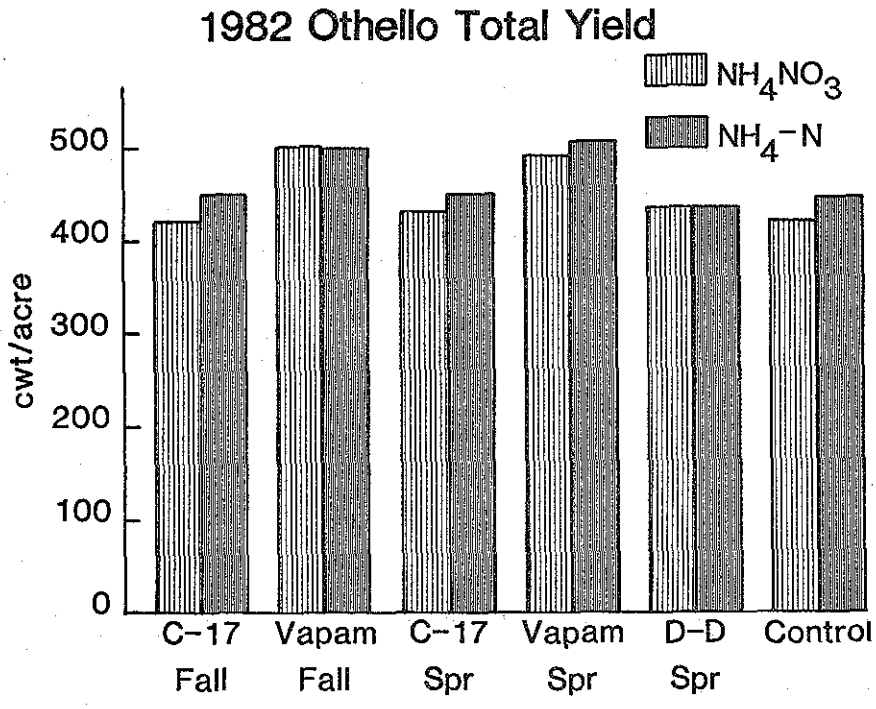


Figure 3.

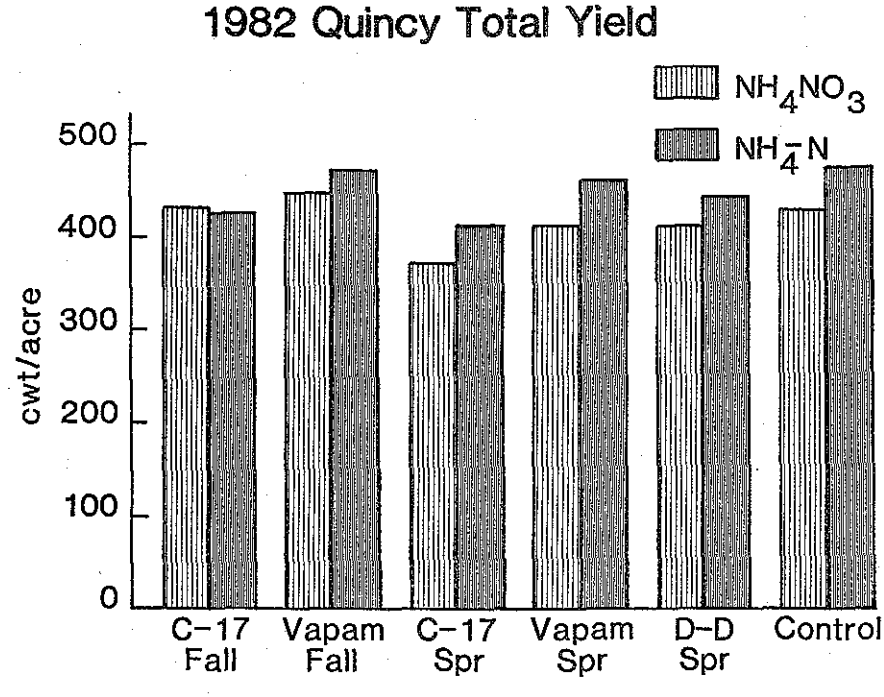
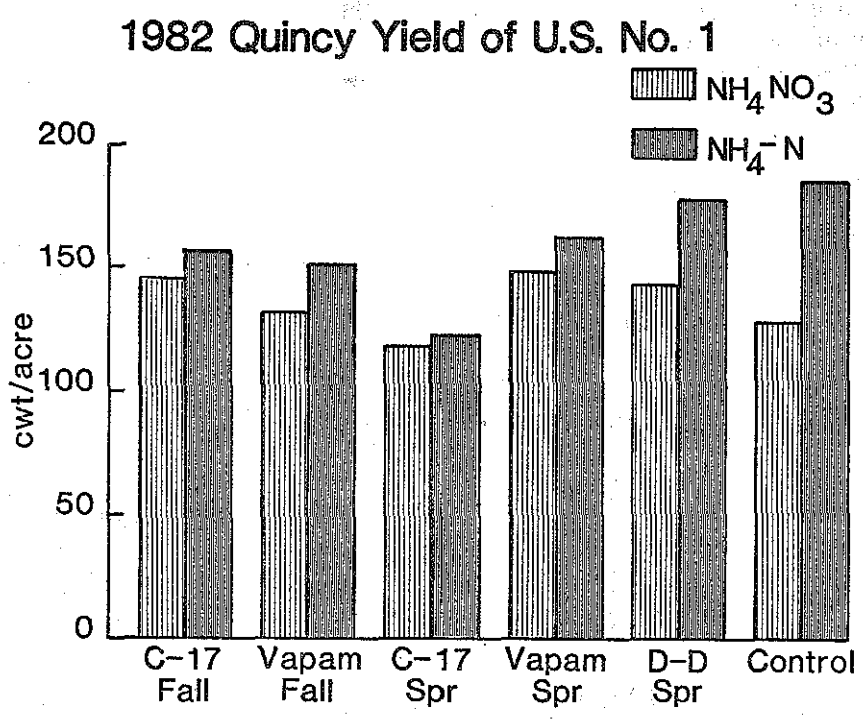


Figure 4.



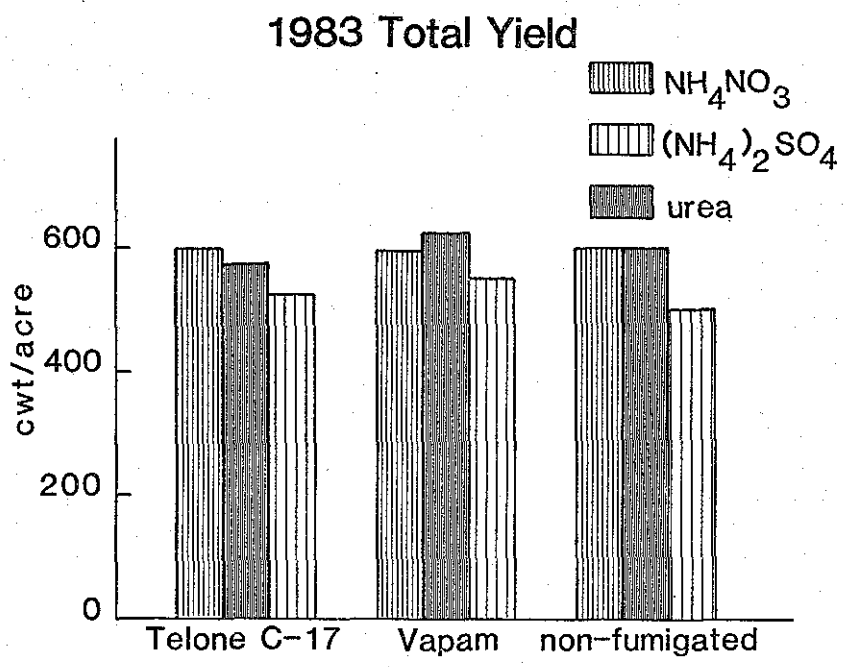
At the Quincy location early blight was evident throughout the plot, but symptoms of Verticillium wilt were not observed. Unlike the Othello location, the Quincy plot had not been planted in potatoes for many years and there probably were few potato pathogens in the soil. This might explain the lack of response by yield to fumigation. The Quincy plot was over-irrigated several times during the growing season, and as mentioned earlier, nitrate nitrogen is quickly leached from the soil. Therefore, the low yields obtained with ammonium nitrate were probably due to less nitrogen being available to the plants than in soil fertilized with only ammonium nitrogen.

To summarize the 1981 and 1982 data, in 1981 ammonium nitrate provided better growth and higher yields than ammonium sulfate and fumigation was not beneficial. In 1982 fumigation had no effect at Quincy and fertilization with ammonium nitrogen resulted in higher yields than fertilization with ammonium nitrate. At Othello fumigation with Vapam^R improved yields but there was no difference between nitrogen sources.

In 1983 Max Hammond conducted still another field study. He chose a field that was very low in residual nitrate, less than one ppm. The fumigation treatments consisted of Telone C-17^R, Vapam^R, and a non-fumigated control. The three nitrogen treatments were ammonium nitrate, ammonium sulfate, and urea. To briefly summarize Hammond's results, fumigation had no effect on total yield but ammonium sulfate reduced yields in both fumigated and non-fumigated soils compared to ammonium nitrate and urea (Fig. 5).

Overall, the three years of field studies were inconclusive and confusing. They did, however, suggest that the response of potatoes to fumigation and nitrogen source may be dependent on many factors. To reduce variability due to these factors several growth room studies were conducted. By growing potatoes under very controlled conditions specific treatment effects could be examined without the complicating interactions of differences in temperature, light, pH, and watering between treatments - complications invariably encountered in field experiments.

Figure 5.



In one study, plants were grown in soil that had been both fumigated and fertilized in the field. The fumigation treatments consisted of Telone C-17^R, Vapam^R, and a non-fumigated control. The two nitrogen sources were ammonium nitrate and aqua ammonia. Throughout the study plants in all treatments appeared healthy and vigorous. At the end of the study we found that neither fumigation nor nitrogen source had any effect on plant growth or yield.

The lack of response to fumigation suggested that there were no pathogens present in the soil, but there are three possibile explanations for the lack of response to nitrogen source: (1) fumigation did not inhibit nitrification, indicating that ammonium was converted to nitrate by the bacteria in the soil; (2) nitrification was inhibited by the fumigant but had recovered by time of planting; or (3) nitrogen form had no effect on plant growth. In other words, the plants did not care whether they took up the ammonium or nitrate form of nitrogen. To examine the latter possibility a series of experiments were conducted in which potatoes were grown in soilless medium. By growing the potatoes in an inert growing medium, we could be sure that the form of nitrogen applied to the medium was actually the form available to the plant.

In one study the effects of ammonium, ammonium plus nitrate, and nitrate on potatoes grown in sand were examined. The nitrogen treatments were applied in balanced nutrient solutions with the pH maintained at 6.0. At the end of the study there were distinct differences in growth of plants in the three nitrogen treatments. Ammonium nitrogen fed plants were small and weak with chlorotic, tightly rolled leaves. In contrast, plants in the nitrate and ammonium plus nitrate treatments were stocky and healthy in appearance. Weights of both roots and shoots were highest with nitrate nitrogen, intermediate with ammonium plus nitrate, and severely reduced with ammonium nitrogen.

Nitrogen source also had an effect on the mineral composition of plant tissues. Plants supplied with ammonium contained lower concentrations of potassium, calcium, and magnesium, and higher concentrations of phosphorus than plants grown on ammonium nitrate or nitrate. We also found that other factors influenced the response of potatoes to nitrogen source. In several other studies the growing medium, soil and solution pH, and even the nitrification inhibitor, N-Serve^R, altered the response of potatoes to nitrogen source. But, in all of these studies ammonium nitrogen was detrimental to potato plant growth and tuber development, and supplying part or all of the nitrogen as nitrate improved growth.

It is clear from our soilless media studies that under certain conditions ammonium nitrogen is detrimental to potato growth and development. But most growers we know do not grow potatoes in pots of sand in a growth room; they grow potatoes in the field. The nitrifying bacteria present in field soils usually convert applied ammonium to nitrate quickly enough that the plants never take up very large quantities of ammonium. What then does this all mean?

Our original hypothesis, based on some casual field observations, was that soil fumigated prior to planting would severely reduce populations of nitrifiers in the soil. Use of ammonium fertilizers could then result in poor growth and reduced yields as a result of excess ammonium uptake. Our field studies, however, showed that nitrifier populations rapidly recovered from the effects of fumigation and high levels of ammonium did not remain in the soil. Consequently, there was no adverse effect on plant growth or yield.

But, our growth room studies indicate that there may be field situations where as a result of fumigation ammonium nitrogen fertilizers have detrimental effects on growth and yield. These situations are: (1) fields that have been fumigated with very high rates of fumigant; (2) fields low in residual nitrate at time of planting; and (3) very cool early season soil temperatures. All these conditions could cause a prolonged inhibition of nitrification and we recommend that care should be taken if such conditions exist until further research indicates otherwise. Based on our studies, unless these conditions do exist, the use of ammonium nitrogen fertilizers on fumigated soil will not adversely affect potato growth or tuber yield. The nitrogen fertilizer of your choice can therefore be used. Our studies also indicate that in fields prone to flooding ammonium fertilizers should be used to reduce nitrogen losses by leaching. In soils very low in residual nitrate fertilizers containing nitrate nitrogen are preferrable.