NITROGEN, MINIMUM TILLAGE, AND THE COLUMBIA BASIN

by
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As federal deadlines near for reports and recommendations concerning nonpoint sources of pollution, considerable interest exists in agricultural management techniques which tend to decrease or even minimize water and air pollution in agricultural areas. Because of its combined potential to lower existing levels of both water and air pollution, the use of minimum tillage procedures for potato production (as described elsewhere in these proceedings) looks particularly promising as a management practice for the Columbia Basin area.

Wind erosion control is provided during minimum tillage management through the maintenance of crop residues on the soil surface, and crop roots and residues in the surface layer of soil, during the normal overwinter period. These residues also aid in soil stabilization against water erosion during early-season furrow irrigation. Nutrient uptake by the cover crop during the fall and early spring periods similarly aids in the utilization of residual nitrogen remaining in the soil following growth of intensively-managed crops. The latter factor is particularly important for shallow-rooted crops such as potatoes, where considerable leaching of soluble nutrients (e.g. nitrate-nitrogen) can occur once the nutrients are below the surface layers of soil.

Experimental results demonstrating a large potential for nitrate contamination of groundwaters adjacent to irrigated potato fields in the Columbia Basin area were presented previously. [2] High concentrations of NO_3-N (5 to 50 times the recommended drinking water maximum) were found in well-managed potato fields, and were readily leached whenever excess irrigation water was applied. Soil solutions beneath the root zone of long-term fertilization plots on the Othello Research Station of Washington State University were shown to contain nitrogen concentrations averaging 15 times the drinking water standard after approximately 400 lbs N/acre had been applied annually for 5 to 6 years. High concentrations of residual nitrogen also were shown to remain in the soil solution of well-managed potato fields at the end of the growing season whenever active crop growth had been maintained to the end of the season. These high nitrogen concentrations persisted during the overwinter and early spring periods, though they had decreased by 5- to 10-fold in surface (root zone) soil by late fall of the following season. A ryegrass cover crop had been planted on the field earlier that fall, so it was uncertain to what extent such decreases arose from nitrogen assimilation into the organic fraction of the soil during the early summer fallow period, and to what extent they arose from nitrogen uptake by the ryegrass. The general trend was encouraging, however, and added fuel to the hope that growth of winter cover crops following potatoes would aid in reducing high residual soil solution nitrogen values to tolerable levels.

In additional cooperative studies with R. Kunkel of WSU, it was demonstrated that carryover of residual nitrogen from one season to the next in the form of crop residues is likely for fields recropped to potatoes. Typical data are given in Table 1 for a 1973 cooperative experiment at the Othello Station investigating both yields and soil solution nitrogen values for potato plots fertilized with either traditional or slow-release forms of nitrogen fertilizer.

The data demonstrate once more the high levels of soluble inorganic nitrogen (predominantly NO_3-N) that exist in potato fields throughout most of the growing season even at low fertilization rates, and throughout the entire season at high fertilization rates. Lower soluble nitrogen levels also are shown to exist in plots fertilized with slow-release nitrogen fertilizers, demonstrating that such fertilizers show promise as a means for lowering nitrogen contamination of ground waters in potato producing areas, once they become economically competitive with traditional nitrogen sources. The main point to be illustrated by the above data, however, is the increases in dissolved soil nitrogen values at mid-season which occured for three of the four treatments. This suggests that mid-summer release of nitrogen from previous crop residues produces more nitrogen then can be readily taken up by the crop in many fields being recropped to potatoes. This trend has been observed repeatedly throughout the Columbia Basin area during our recent cooperative experiments with R. Kunkel and co-workers. The only exception to this trend for the experiments summarized in Table 1 occured with the low fertilization rate, slow release nitrogen plots. Soluble nitrogen levels at midseason from fertilizer applied to these plots appears to have been insufficient to satisfy crop needs, so that all nitrogen being released from decomposing crop residues was rapidly taken up by the crop.

Table 1. Average values for dissolved inorganic nitrogen in the soil solution for soil samples taken from the top 2 feet of soil, for 1973 slow-release nitrogen plots at the Othello Station.

Treatment	5-24	Sampling Date 7-10	7-24	8-23
		(mg/liter)		
150 # Traditional	162	88	159	18
150 # Slow N	220	53	24	15
450 # Traditional	291	422	663	452
450 # Slow N	283	231	431	198

The high soil solution nitrogen levels remaining following potato production in much of the Columbia Basin area, with supplementation of these levels by further release of nitrogen from crop residues during the following crop season, dictates the need for information on the uptake of nitrogen by succeeding crops in order to minimize nitrogen leaching losses. The marked decreases in soil solution nitrogen levels which were observed during an early-summer fallow period and subsequent growth of a ryegrass crop (described above) suggest as one possibility the uptake of residual nitrogen by cover crops grown during the succeeding over-winter period. Data on the levels of soluble nitrogen remaining in the soil profile in April of 1974 following growth of a winter cover crop on minimum tillage plots at the Othello Station (descried by R. Kunkel elsewhere in these Proceedings) are summarized in Table 2.

Table 2. Average values for dissolved inorganic nitrogen in the soil solution for soil samples taken from the minimum tillage plots on the Othello Station in April of 1974.

Depth	Wheat Plots Average	Range	Ryegrass Plots Average	Range
(feet)	(mg/liter)		(mg/liter)	
0-1	22	4-45	14	5-35
1-2	10	2-18	15	1-27
2-3	82	25-183	128	24-166
3-4	149	95-224	184	70-272
4-5	58	5-106	43	4-102
5-5-1/2	18	9-38	14	2-31

Average values for soluble nitrogen in the top two feet of soil were low in all cases, and never more than 2 times the maximum drinking water standard. Much of this appears to reflect uptake of soluble nitrogen by the cover crop, although the low values could also reflect leaching of nitrate from the surface soil layer during the over-winter period, with little conversion of additional nitrogen from the ammonium to the nitrate form because of cool soil temperatures during the early spring.

Values for soil solution nitrogen were markedly higher (averaging 8 to 18 times the maximum drinking water standard) for the 2 to 4 foot soil depth. These high levels of nitrogen had leached well below the normal rooting zone of potatoes at this location, and foliage of the cover crop already had been killed at the time of sampling, so such nitrogen was beyond the depth of potential crop uptake, and was subject to leaching during the 1974 crop season. Values at each of the 12 sampling sites in the field varied somewhat, but the zone of high nitrogen concentrations occured at between 2 and 5 feet of depth in all cases, with overlying and underlying soil exhibiting low nitrogen concentrations. Maximum soluble nitrogen values at all sites were of the same order of magnitude (95-272 mg/liter), suggesting that the movement of nitrogen followed a uniform field-wide fertilization, such as applied to the field in the fall of 1973 during cover crop establishment. No regular differences between the wheat and ryegrass crops were evident from the data.

A reasonable explanation of the data in Table 2 is provided by the 1973-74 fall and winter rainfall data at Othello, as summarized in Table 3.

Table 3. Precipitation at Othello during the 1973-74 fall and winter period.

Month	Precipitation (inches)
September	0.51
October	1.24
November	3.61
December	2.86
January	1.30
February	0.87
March	0.00
	10.39 inches

Precipitation was approximately 50% higher at the site during this period than the long-term average for comparable periods, so the initial year of minimum tillage experimentation was carried out under abnormally wet conditions. As the soil at the Othello Station retains an average of about 2 inches of water per foot of depth at "field capacity", there was enough precipitation to move fertilizer nitrates to the 5 foot depth at any sampling site which was slightly more coarse-textured than the average, or at any site where water might tend to accumulate briefly in shallow surface depressions. To the values of Table 3 should be added the quantities of irrigation water applied for stand establishment and early fall irrigation of the cover crop. Even with surface evaporation during the windy fall season, and evapotranspiration losses by the crop during the entire over-winter period, there appears to have been adequate water available at the Othello Station to produce the leaching reported in Table 2.

The minimum tillage treatments used for this initial study not only failed to prevent nitrogen leaching following cropping to potatoes, but actually may have contributed additional nitrogen from the heavy fall fertilization to be moved through the soil during the wet over-winter period. The importance of minimum fertilization for cover crop establishment is thus demonstrated, as well as the importance of adding fall applied nitrogen in predominantly the ammonium (including anhydrous ammonia) form and at a time when it will be converted only slowly to the nitrate form during the remaining fall months. Fumigation has been stressed as an important management practice for fields recropped to potatoes, so any die-back in the soil population of nitrifying bacteria which accompanies fumigation may aid by retarding nitrate formation and subsequent leaching of nitrogen. By the time the soil bacterial population has multiplied again following fumigation, the average soil temperature may be low enough (less than approximately 50^{o}F) to inhibit conversion of ammonium nitrogen to the nitrate form. Fortunately, many grass cover crops are able to use either ammonium or nitrate forms of nitrogen in satisfying their nutritional needs.

Another method for preventing the nitrification of fall-applied ammonium fertilizers is their late application, or their application to dry soils, so that either soil temperature or soil moisture status is unfavorable for subsequent microbial conversion of nitrogen to the nitrate form. However, such conditions are unsatisfactory for establishment of the winter cover crop to be used for erosion control. Additional work must be done to establish proper fertilization timing and associated management techniques to maximize early fall growth of the cover crop while minimizing nitrogen leaching during the over-winter period. Use of only a small quantity of "starter" nitrogen for the cover crop, with the main application of nitrogen for the next season's potato crop to be made either during the spring planting operation, or through the sprinkler system during the potato growing season, may prove to be the most efficient means of nitrogen management in such potato recrop systems.

As additional evidence that excess nitrogen is being leached in irrigated areas of the Pacific Northwest, one can cite the work of Nelson and Weaver [3/] or Carter et al [4/]. Nelson and Weaver showed a 5-fold increase in the tonnage of nitrogen being leached from soils of the Wapato Project of central Washington between 1941-42 and 1970-71, with an average nitrogen loss during the latter period of 28 lbs/acre. Carter et al showed an average nitrogen loss from the Twin Falls project of central Idaho of 30 lbs/acre. Although substantial losses of nitrogen are occuring for many irrigated lands of the Northwest, considerable promise for utilization of residual nitrogen exists if nitrogen and water have been managed properly, so that most residual nitrogen is left within the rooting zone of the cover crop.

Further evidence of nitrogen excesses in many potato fields of the Columbia Basin area were obtained from average yield data for plots monitored during Kunkel's 1973 experiments on grower's fields throughout the Basin. Soil solution soluble nitrogen levels were high during the growing season and frequently at season's end, and generally reflected midseason release of nitrogen from previous crop residues, as pointed out above. Yield data for several sets of plots in which soil solution nitrogen values had been monitored during 1973 are given in Table 4.

Table 4. Yield data for selected plots from slow-release nitrogen experiments established for the 1973 season in grower's fields of the Columbia Basin area.

Location	Soil Type	Sprinkler System	Fertilizer Source	Nitrogen Fertilization Rate * Low	Medium	High
Horse Heaven Hills	Sandy loam	Center-pivot	Traditional	-	356	348
			Slow N	-	362	340
Othello	Silt loam	Solid-set	Traditional	649	667	649
			Slow N	587	660	651
Othello Station	Silt loam	Furrow (rill)	Traditional	584	546	509
			Slow N	553	623	543
Moses Lake	Sandy loam	Furrow (rill)	Traditional	428	476	510
			Slow N	334	406	474

*Actual rates = 424 and 474 lbs N/acre at the Horse Heaven Hills site; 150, 300 and 450 lbs N/acre for the Othello and Othello Station sites; and 150, 250 and 350 lbs N/acre for the Moses Lake site.

A negative yield response to nitrogen fertilization was obtained for the highest fertilization rate at all locations except Moses Lake, where relatively low fertilization rates and high leaching associated with furrow irrigation of the sandy soil resulted in nitrogen stress at all fertilization rates. A negative response at the intermediate fertilization rate also was observed when traditional fertilizers were used at the Othello Station, though slow-release fertilizers apparently produced sufficiently low soil solution nitrogen values to produce some nitrogen stress for the lowest fertilization rate at this location. All fertilization rates employed for these experiments were well within the range of commercial rates presently used for grower's fields in the Columbia Basin area. Many growers thus are operating at fertilization rates which offer considerable potential for incomplete nitrogen utilization by the crop, and for leaching of excess nitrogen during the over-winter period and succeeding cropping seasons.

Several experiments investigating better ways to manage nitrogen fertilizer for potato production have been carried out in cooperation with R. Kunkel of WSU in recent years. One such study has investigated different timings and rates for sprinkler-applied nitrogen in order to maximize potato production while minimizing dissolved nitrogen levels and nitrogen leaching during the growing season. Use of 300 lbs N/acre applied bi-weekly provided the highest total yields in this experiment on the Othello Station, with lower yields obtained at higher fertilization rates and at less frequent application intervals. In a second experiment, yields were determined for plots on the Othello Station maintained at nearly-constant petiole NO_3-N levels throughout the growing season. Preliminary results indicate that considerably lower petiole NO_3-N levels may be maintained in some cases than commonly supposed marginal without resulting in serious lowering of total yield or tuber quality. Analyses are being completed of the reasons for such high yields under conditions normally regarded to be nitrogen-limiting, to determine whether they can be duplicated on a commercial basis. In any event, considerable research remains before all aspects of nitrogen management for maximum crop production and minimum leaching of nitrogen in the Columbia Basin area are understood. This is particularly true for minimum tillage management conditions.

CONCLUSIONS

Further evidence is presented to show that high levels of dissolved nitrogen exist for many potato lands of the Columbia Basin area, with residual dissolved nitrogen remaining at the end of the growing season, and with additional quantities of nitrogen released from crop residues during the succeeding crop season. The use of the winter cover crop in minimum tillage management as a soil nitrogen "scavenger" appears both feasible and promising. However, for the initial minimum tillage experiments conducted on the Othello Research Station in 1974, large concentrations of dissolved inorganic nitrogen from fall-applied fertilizers were leached below the crop root zone during the relatively wet 1973-74 over-winter period. Further investigations are needed into proper nitrogen management during the potato season and during establishment and growth of succeeding cover crops.

1/ Associate Soil Scientist, Washington State University, Pullman. Portions of this study were funded by a grant from the Environmental Protection Agency (EPA).

2/ McNeal, B. L. and R. Kunkel. 1973. Nitrate leaching following potato fertilization. Proc. 12th Wash. Potato Conf., Moses Lake. pp 103-109.

3/ Nelson, C. E. and H. Weaver. 1972. Salt balance for the Wapato Project for 1970-71 compared with the salt balance for 1941-42. Wash. Agric. Expt. Sta. Bull. 743.

4/ Carter, D. L. S. A. Bondurant and C. W. Robbins. 1971. Water-soluble NO_3 nitrogen, PO_4-phosphorus, and total salt balances on a large irrigation tract, Soil Sci. Soc. Amer. Proc. 35: 331-335.