EPA-600/2-76-158
September 1976

Environmental Protection Technology Series

NITROGEN AND IRRIGATION MANAGEMENT TO REDUCE RETURN-FLOW POLLUTION IN THE COLUMBIA BASIN

Robert S. Kerr Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment, and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

EPA-600/2-76-158
September 1976

NITROGEN AND IRRIGATION MANAGEMENT TO REDUCE RETURN-FLOW POLLUTION IN THE COLUMBIA BASIN

by

Brian L. McNeal
and
Bobby L. Carlile

Department of Agronomy and Soils
Washington State University
Pullman, Washington 99163

Grant No. S-801187

Project Officer

C. E. Veirs
U.S. Environmental Protection Agency
Region X
Seattle, Washington 98101

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY
ADA, OKLAHOMA 74820

DISCLAIMER

This report has been reviewed by the Robert S. Kerr Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

Cooperative field studies have evaluated dissolved-N levels and leaching, and corresponding crop yields, for potato production practices in the Columbia Basin area of Washington. High dissolved-N levels (with resultant high potential for return-flow pollution) were found throughout the growing season in well-managed potato fields, with levels decreased by decreasing fertilization rate, use of slow-release N fertilizers or nitrification inhibitors, or sprinkler application of N fertilizers.

Careful water management with solid-set sprinklers proved capable of maintaining dissolved-N within the root zone of subsequent crops by season's end, even on very sandy sites. Alternate-furrow irrigation proved effective in "trapping" banded fertilizer N within the plant root zone on heavier-textured furrow-irrigated soils. Periodic "mining" of residual N by other crops in the rotation would still be necessary to prevent eventual return-flow contamination, however.

Site-to-site sampling variability necessitates the use of composited soil samples, rather than fixed-position soil solution extraction cups, for adequate monitoring of N in soils of this area. Neither dissolved soil N nor plant petiole nitrate-N proved to be reliable predictors of crop N needs at the high residual soil N levels commonly found.

This report was submitted in fulfillment of Grants Number 13030-FST and S-801187, by Washington State University, Pullman, under the (partial) sponsorship of the Environmental Protection Agency. Work was completed as of October, 1974.

CONTENTS

Sections		Page
I	Conclusions	1
II	Recommendations	6
III	Introduction	8
IV	Experimental Procedure	11
	1971 Season	11
	1972 Season	15
	1973 Season	17
	1974 Season	19
V	Results and Discussion	21
	1971 Season	21
	1972 Season	40
	1973 Season	52
	1974 Season	84
VI	References	103
VII	Publications	104
VIII	Appendix	105

TABLES

No.		Page
1	Summarized Climatological Data, 1971-1969, Block 21 Site	22
2	Monthly Water Applications, Block 21 Site	23
3	Summarized Furrow Runoff Data, Block 21 Site	24
4	Total Yield Data, Block 21 Site	26
5	Tuber Quality Data, Block 21 Site	27
6	Average Dissolved Inorganic N, Soil Solution, Block 21 Site	29
7	Dissolved Inorganic N, Paired Locations, Block 21 Site	30
8	Soil Nitrate N, Sprinkler-irrigated Plots, Block 21 Site	31
9	Soil Nitrate N, Furrow-irrigated Plots, Block 21 Site	32
10	Dissolved Inorganic N, Nitrification Retardant Plots, Block 21 Site	34
11	Irrigation Water and Runoff Water Analyses, Block 21 Site	35
12	Averaged Values for Dissolved Inorganic N, Block 21 Site	37
13	Average Soil Parameters as a Function of Depth, Block 21 Site	38
14	Comparison of Extraction Cup and Soil Sample N Values, Block 21 Site	41
15	Dissolved Inorganic N, Furrow-rate Experiment, 1972	42
16	Dissolved Inorganic N, Suspension Fertilizer Experiment, 1972	43
17	Dissolved Inorganic N, Suspension Fertilizer Experiment, Fall of 1972	44
18	Dissolved Inorganic N, 1971 Suspension Fertilizer Experiment, 1972	45

TABLES (continued)

No.		Page
19	Dissolved Inorganic N, Fertilizer Factorial Experiment, Fall of 1972	47
20	Available P and K, Fertilizer Factorial Experiment, Fall of 1972	47
21	Dissolved Inorganic N, Slow-Release N Experiment, 1972	49
22	Variations in Soil Silt Content, Experimental Plots, Othello Station	51
23	Summarized Comparison of Extraction Cup and Soil Sample N Values, Othello Station	53
24	Dissolved Inorganic N, Suspension Fertilizer Experiments, Tri-Cities Area, 1973	55
25	Dissolved Inorganic N and Yield Data, Suspension Fertilizer Experiments, Horse Heaven Hills Area, 1973	56
26	Dissolved Inorganic N and Yield Data, Suspension Fertilizer Experiments, Moses Lake Area, 1973	58
27	Dissolved Inorganic N and Yield Data, Suspension Fertilizer Experiments, Othello Area, 1973	61
28	Dissolved Inorganic N, Slow-release N Experiments, Tri-Cities Area, 1973	63
29	Dissolved Inorganic N and Yield Data, Slow-release N Experiments, Horse Heaven Hills Area, 1973	65
30	Dissolved Inorganic N and Yield Data, Slow-release N Experiments, Moses Lake Area, 1973	67
31	Dissolved Inorganic N and Yield Data, Slow-release N Experiments, Othello Area, 1973	69
32	Dissolved Inorganic N and Yield Data, Slow-release N Experiments, Othello Station, 1973	72
33	Additional Dissolved Inorganic N Data, Slow-release N Experiments, Othello Station, 1973	73
34	Petiole Nitrate-N Levels, Suspension Fertilizer and Slow-release N Experiments, 1973	76
35	Correlation of Soil Dissolved Inorganic N and Petiole Nitrate-N with Potato Yield and Quality, 1973	78

TABLES (continued)

No.		Page
36	Dissolved Inorganic N and Yield Data, Nitrogation Experiment, Othello Station, 1973	80
37	Dissolved Inorganic N and Yield Data, Sprinkler Irrigation Rate Experiment, Othello Station, 1973	82
38	Dissolved Inorganic N, Extraction Cup Values, Othello Station, 1973	83
39	Summarized Petiole Analyses, By Fertilization Rate, Petiole N Experiment, Othello Station, 1974	85
40	Summarized Petiole Analyses, By Variety, Petiole N Experiment, Othello Station, 1974	86
41	Yield Data, Petiole N Experiment, Othello Station, 1974	88
42	Yield Data Correlated with Petiole Nitrate Levels for Entire Season, Petiole N Experiment, Othello Station, 1974	89
43	Yield Data Correlated with Petiole Nitrate Levels Prior to August 15, Petiole N Experiment, Othello Station, 1974	90
44	Di-Syston Analyses, Di-Syston Experiment, Othello Station, 1974	92
45	Yield Data, Di-Syston Experiments, Othello Station, 1974	93
46	Soil Analyses, Sprinkler-irrigated Di-Syston Plots, Othello Station, 1974	94
47	Soil Analyses, Furrow-irrigated Di-Syston Plots, Othello Station, 1974	96
48	Properties of Runoff Samples, Furrow-irrigated Plots, Othello Station, 1974 and 1973	99
49	Dissolved Inorganic N and Rainfall Data, Minimum Tillage Plots, Othello Station, 1974	101

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the helpful support, field plot supervision and maintenance, and yield data provided for the Block 21 site by personnel from the Irrigated Agriculture Research and Extension Center, Prosser, including J. E. Middleton, S. Roberts, and T. A. Cline. Similarly, the cooperation, field plot supervision and maintenance, and yield data provided by R. Kunkel and N. M. Holstad of the Department of Horticulture, Washington State University, Pullman, was invaluable and essential to the remaining studies.

Field sampling was conducted by numerous students in addition to the authors, including C. P. Diaz, T. Dechert, J. T. Leifer, W. E. Goode, L. S. Peterson, T. Waszielewski, and K. L. Drecksel. Petiole sampling and analyses were performed by Horticulture Department personnel, under the supervision of R. Kunkel.

Laboratory analyses were performed under the capable supervision of N. M. Ellsworth, with analysts including C. T. Hatch, D. Harston, C. P. Diaz, T. Dechert, T. H. Chaudhary, W. E. Goode, J. T. Leifer, T. Waszielewski, and S. Johnson.

The support of the project by the Environmental Protection Agency and the help provided by Mr. C. E. Veirs, the Grant Project Officer, is acknowledged with sincere thanks. Additional support for the studies was provided by the College of Agriculture Research Center, Washington State University, Pullman.

SECTION I

CONCLUSIONS

High levels of dissolved inorganic nitrogen (primarily nitrate-N) exist in soil solutions from within and beneath potato fields of the Columbia Basin during the cropping season. Such values frequently exceed several hundred mg N/liter early in the season, with minimum values of 20-60 mg N/liter commonly persisting in the fields even at season's end. When compared to the recommended drinking water maximum of 10 mg N/liter, this indicates a considerable potential for ground water and drainage water contamination by soil solutions displaced whenever excessive irrigation water usage occurs in this area.

Normal furrow irrigation of potatoes on sandy soils of the Basin produced extensive leaching of N and required from 5 to 15 times the quantity of water required for efficient sprinkler irrigation at the same location. Alternate-furrow irrigation (where two adjacent irrigation furrows are never wet concurrently) "trapped" much of the fertilizer N in the plant root zone and produced considerably less leaching of N.

Careful irrigation with solid-set sprinkler systems, at quantities dictated by micrometeorological or pan evaporation data, produced near-maximum yields of high-quality tubers even on extremely sandy soils, while still maintaining any high levels of dissolved-N from the current crop season in the top 60 to 120 cm of soil, where it could be removed by subsequent crops in the rotation. However, there was a common tendency to over-irrigate late in the season, when plants had matured and crop water needs had diminished. Center-pivot irrigation appeared to produce excessive leaching of N in some portions of the irrigated field.

Increases in dissolved-N consistently were observed with increased fertilization rate, so that greater leaching and subsoil contamination by N occured at the higher fertilization rates. Increases in N concentration were not strictly proportional to fertilization rate, with a 6-fold increase in fertilization rate commonly producing only a 2- to 3-fold increase in dissolved-N levels of the soil solution.

High residual levels of N in the soil solution persisted from fall until spring, unless leached by over-winter rains. High residual-N levels were reduced to a more-nearly acceptable range during a subsequent fallow period or following subsequent growth of a deep-rooted crop.

An increase in dissolved-N levels was observed at mid-season, which may be due to release of N from residues of the preceeding crop.

Deep-leached N appeared to be neither assimilated nor denitrified to an appreciable extent, with long-term application of 450 kg N/hectare leading to subsoil dissolved-N concentrations of 150 mg/liter at a silt loam site. Subsoil dissolved-N concentrations of 20-50 mg/liter persisted even in N-stressed fields, unless such solutions were diluted or leached subsequently by additional drainage waters. Once beneath the plant root zone, the dissolved-N thus would constitute a continual hazard for ground water contamination in the area.

Use of microbial nitrification inhibitors (such as N-Serve) lowered soil dissolved-N concentrations and reduced the leaching of N from the plant root zone. Lower leaching losses were obtained for urea + N-Serve than for NH_4NO_3 + N-Serve, with N apparently not accumulating in the former case because plant uptake occurred as rapidly as N was converted to the nitrate form.

Use of slow-release N fertilizers (such as sulfur-coated urea or urea-formaldehyde) substantially lowered dissolved-N levels. The lowered dissolved-N values (commonly 1/2 or less of those obtained from comparable rates of traditional fertilizers) led to lowered leaching losses at sandy or over-irrigated sites. However, higher residual-N levels often remained at the season's end in plots fertilized with slow-release fertilizers, due to lowered uptake and leaching losses.

"Nitrogation" (sprinkler application of nitrogen during normal irrigation operations) produced little evidence of substantial N leaching even at high fertilization rates and infrequent application intervals. However, dissolved-N levels of 10-50 mg/liter persisted in the nitrogation plots, with substantially higher values near the season's end if nitrogation was prolonged into the late-season period of decreased plant water uptake.

Sprinkler irrigation at 1.5 times the rate predicted from pan evaporation data produced the highest total yields at a sandy site, despite some late-season leaching of N. Higher sprinkler rates decreased potato yields due to excessive leaching of N, and lower rates led to lowered yields because of uneven water distribution under the windy Columbia Basin conditions (although the latter was less critical at less sandy sites). Tuber quality increased slightly at the higher sprinkler application rates. Early excess sprinkler irrigation for wind erosion control produced N leaching and gave lowered yields if N was applied only at planting time, but side-dressed or sprinkler-applied N later in the season completely offset this effect. Lowered overall yields on furrow-irrigated sandy soils were lowered even more for the extreme head (heavily-leached) and tail (water-stressed) portions of the field. The high water needs of the potato crop make proper water and N management essential in the prevention of return-flow contamination in this area.

Fertilization rates of 220 to 450 kg N/hectare generally were sufficient for maximum yield of high-level tubers at the several experimental locations sampled throughout the Columbia Basin area. Yields of U.S. No. 1 tubers throughout the Columbia Basin were depressed by high nitrogen application rates. This may have been due to insufficient growing season length for the amount of N applied, to excessive vegetative growth, or to early-season salt effects resulting from high concentrations of salt in the fertilizer band. In any event, over-fertilization thus can be argued against on both environmental and economic grounds. Slow-release N fertilizers gave as good or better yields than traditional fertilizers, and particularly at the higher fertilization rates. Lower yields from the slow-release forms on some of the more N-stressed plots might have been overcome with small amounts of starter N applied at the time of planting. The less-soluble forms of slow-release fertilizers generally gave higher yields than the more-soluble forms, unless N stress was present.

Fumigation of recropped potato lands may have retarded nitrification and N leaching, although fumigated plots often required more fertilizer N, due to the higher overall yields produced. Tailoring N application rates to actual plant populations (which are difficult to predict in advance) appeared to produce higher yields without correspondingly higher residual dissolved-N levels.

Petiole NO_3-N levels decreased as the season progressed, and generally increased with increasing N-fertilization rate. However, no evidence of a "critical" plant petiole nitrate-N level was found for petiole levels above 5,000 ppm nitrate-N. As a critical level of 10,000 ppm petiole nitrate-N is commonly recommended in the area, this may account for some of the apparent excessive usage of N on many potato crops in the Basin. Petiole nitrate-N and rootzone dissolved-N were not well correlated for plots having fertilizer banded at moderate to high rates, due to restricted N uptake until the band became more diffuse later in the growing season. Total yield or tuber quality could be predicted from dissolved soil N or petiole nitrate-N only for N-stressed (e.g.,highly leached) plots. In general, neither of these parameters were adequate yield predictors throughout much of the Columbia Basin area.

Runoff waters from furrow-irrigated plots generally contained less than 1 to 2 mg/liter dissolved inorganic N, with turbidity values ranging from 300 to 600 Jackson turbidity units (JTU) for both sandy and silt-loam sites early in the season, and decreasing to 20 to 40 JTU as furrows stabilized by mid-season. Runoff from a furrow-irrigated sandy site averaged 6 to 9 percent of the water applied to 400-foot runs.

Soil-test phosphorus (P) and potassium (K) levels increased 5-fold and 2-fold, respectively, in the top 30 cm of soil for 450 kg/hectare (oxide form) fertilization rates on long-term fertility plots. Values for soil-test P also were increased 3-fold for the 30-60 cm depth of soil in these same plots, with neither P nor K increased at subsequent plot depths. Fertilization at a rate of 450 kg P_2O_5/hectare increased soil-test P to the highest soil-test category in only 2 years. Only small increases in the P and K levels of adjacent experimental plots resulted from wind or water transport of heavily-fertilized surface soil particles. The relatively small increases in soil-test K levels in the long-term fertility plots may reflect both high levels of plant uptake of this element, and a tendency towards its fixation in unavailable forms by soils of the area.

The systemic pesticide Di-syston disappeared from fertilizer bands by season's end when used at recommended rates. However, Di-syston persisted in the fertilizer bands at higher application rates. Di-syston appeared to be lost most rapidly from sprinkler-irrigated plots. No effects of high residual Di-syston levels on crop yields were evident.

Soil textural variations within both a sandy and a silt loam experimental site were not large, despite the fact that each site had been leveled to accomodate surface irrigation. However, surface soil soil-test P and K values varied much more, and were highly correlated. Such variations probably arose both from the initial leveling operations and from subsequent fertilization and/or crop utilization patterns. Soil sampling variability for dissolved-N levels was extremely large. Variability in reported N levels was nearly as large for sprinkler-irrigated plots as for furrow-irrigated plots, for the lower profile as for the upper profile, for broadcast fertilizer applications as for banded applications (especially late in the growing season), and for soil samples as for samples from soil solution extraction cups. Despite wide variations at any point in space or time, seasonal average dissolved-N values for extraction cups and soil samples were essentially identical. Hence the sampling, storage, and data extrapolation procedures used for the study appear to have been satisfactory.

Ceramic extraction cups constituted a poor sampling procedure for dissolved-N, due to extremes in concentration encountered at lateral soil distances of only a few meters. The cups also failed to consistently extract from all depths at all times in non-flooded fields (producing variable sampling populations from one period to the next), had a large probability that solute peaks would occur between extraction cup depths on any given sampling date, and often were at variable lateral positions with respect to the fertilizer band. Reliance on even continuous sampling would not circumvent such problems, because of the widely different rates and patterns of water movement at points only a few meters apart in the field. Extrapolation from a few extraction cup sites to an entire irrigated field appears to be a completely unacceptable approach for monitoring or verification of fertilizer leaching patterns in the area.

Water flux values (estimated from tensiometer and water content data) ranged from 0.02 to 2 cm/day during the growing season at a well-irrigated silt loam site typical of older potato lands in the Columbia Basin. Water movement may have been restricted by a compacted layer which forms at depths of 20 to 30 cm in fields of the area. Although nitrogen flux values vary continuously throughout the growing season, an average downward water flux of 0.1 cm/day for 120 days would leach 59 kg N/hectare at an average dissolved-N level of 50 mg/liter.

SECTION II

RECOMMENDATIONS

Because of the high dissolved-N levels present even in well-managed potato fields, good water management is essential to the prevention of local ground water and drainage water contamination. Carefully regulated solid-set sprinkler systems appear most capable of restricting N leaching under the windy Columbia Basin conditions, with water application rates estimated (as has been recommended previously) from evaporation pan or micrometeorological values during mid-season and from soil sampling during the early-season and late-season periods of decreased water needs. Center-pivot sprinkler systems also can be used effectively in this area, although water distribution patterns and N application practices should be carefully investigated if deep percolation and surface runoff losses are to be minimized.

Some leaching losses of fertilizer N must be accepted for furrow irrigation systems in the area, because of their higher water requirements for most soils of the Columbia Basin. However, use of band-applied fertilizers coupled with alternate-furrow irrigation techniques can substantially lower N leaching losses at many furrow-irrigated locations.

As economics permits, management practices which minimize the levels of dissolved-N present in the soil during the growing season should be selected. These include the use of slow-release N fertilizers or nitrification inhibitors, of sprinkler-applied N ("nitrogation") techniques, of lower rates of fertilizer N than currently employed in many situations, and of deep-rooted cover crops or of periodic alternate crops to utilize residual N prior to potato recropping. Over-winter cover crops should be grown with only minimum levels of starter N applied at the time of planting, to enhance utilization of residual dissolved N. Fall application of fertilizer N for subsequent potato crops should be employed only under conditions where essentially no nitrification of this N will occur prior to the over-winter period (because of moisture-temperature relations or because of nitrification inhibition due to fall fumigation practices).

Recommended minimum petiole nitrate-N levels for high-level potato production should be lowered to 5,000 ppm for many portions of the Basin, because of demonstrated high-level production even at this petiole nitrate-N level.

Replicated and composited soil samples taken across row-furrow sets should be used to characterize dissolved-N levels in soils of the area. Reliance should not be placed upon a few soil solution extraction cups placed in a "typical" field, for behavior at a single site is rarely indicative of average behavior throughout an entire irrigated field.

Domestic water supplies from shallow ground water sources in potato-producing areas should be tested regularly for dissolved-N contamination, with alternate supplies (such as bottled water) seriously considered for nursing mothers and young infants in such areas.

SECTION III

INTRODUCTION

High-level potato production normally requires large quantities of both water and nutrients. Such conditions maximize the potential for ground water and drainage water return-flow contamination during crop growth. Hence, the crop makes an excellent indicator of management techniques required to minimize return-flow contamination from intensively-cultivated row crops in the irrigated Columbia Basin area of Washington. The fact that the state of Washington is second in the nation in total potato production, and leads the nation in potato production per acre, further adds to the acceptability of the potato as an indicator crop for this area.

Field studies of a research and demonstration nature normally require large expenditures of time and money for the collection of even minimal amounts of data. The current study was proposed as an extension of a cooperative effort between Washington State University (WSU) and the U.S. Bureau of Reclamation (USBR), with the original study being designed to demonstrate water requirements and crop yields on extremely sandy sites proposed for irrigation development in the Columbia Basin. It was a logical extension to monitor return flow contamination associated with the various management practices under examination. Such monitoring was conducted during the initial year of EPA funding, in cooperation with J. E. Middleton, S. Roberts, and T. A. Cline of the WSU Irrigated Agriculture Research and Extension Center, at Prosser. Because of funding delays, however, the original WSU-USBR cooperative study was completed before subsequent crop seasons could be studied. Thus,an additional cooperator was sought.

The project leaders were fortunate to find a willing cooperator in Dr. Robert Kunkel of the Department of Horticulture at WSU, whose large-scale field operations provided numerous opportunities to monitor return-flow contamination associated with a wide variety of potato management practices. Although some small-scale cooperative field plots were established as well, most work during the remainder of the project period centered around the monitoring of soil solutions within and beneath many of Dr. Kunkel's potato management plots in the Columbia Basin area. The small loss of individual freedom associated with this approach was offset many-fold by the large number of plots available for monitoring during this period.

Original objectives of the project were:

"To determine the quantities of nutrients, sediments, pesticides, and total salts carried by seepage waters under varied irrigation methods and fertility treatments.

"To demonstrate that the contamination of surface water and local ground water is significantly influenced by the method and efficiency of irrigation. The advantages of proper irrigation practices and fertilizer management in the control of pollutants will be a prime objective in this study.

"To develop and promote good water management practices as a means of reducing water quality degradation and to demonstrate the economics of these practices under intensive irrigation agriculture."

Of these objectives, the goals dealing with pesticides and economics obviously have been short-changed. Pesticide analyses were supplanted in many cases by the larger-than-anticipated numbers of nutrient and total solute (salt) analyses available from the actual cooperative studies. The goal dealing with economics soon became regarded as overly-naive, in light of the many management choices associated with the actual study. Economic considerations logically should constitute a separate, additional study once adequate sediment data for the Northwest are available. Such a study would permit a valid comparison to be made of trade-offs between drainage water and runoff water contamination under various management conditions.

The original plan of operation for the project was as follows:

"Field research and demonstration studies are proposed to evaluate irrigation techniques and fertilization management practices for minimization of water quality impairment in irrigation waste water. Water and nutrient movements will be measured under both furrow and sprinkler systems at various water application rates and fertility treatments. Suspended sediment in surface waste water will be monitored and the distribution of nutrients between the aqueous and solid phases will be examined. Total salt removal under various treatments will also be studied.

"Urea and ammonium fertilizers in combination with a nitrification retardant and slow-release formulas will be studied in an attempt to reduce leaching losses of nitrogen during early season irrigation.

"Porous cups will be utilized to collect samples of soil solution for analyses. These cups will be buried at varied depths in the soil and at sufficient locations in and around each plot to measure the quality of water moving through the profile.

"Techniques for the "in situ" measurements of soil moisture flux will be further developed and tested in field plots in an attempt to obtain more accurate water mass balance equations under field conditions."

Of these plans, only the nutrient distributions between sediments and associated runoff waters, and the "in situ" flux measurements, were short-changed. Once again, the nutrient distribution studies were supplanted by the larger-than-anticipated numbers of nutrient and total salt analyses available from the actual cooperative studies. Field moisture fluxes proved to be estimated with sufficient accuracy from tensiometer readings and field water content data, so that in-situ flux measurements were no longer essential to the study.

The remaining objectives and experimental plans were fulfilled to a greater extent than had been anticipated, due to the excellent cooperative relationships which existed during the study period.

SECTION IV

EXPERIMENTAL PROCEDURE

1971 SEASON

The 1971 cropping season (the initial year of project funding) was the third and final year of field research at the Block 21 experimental site. This location had been selected for a cooperative study by personnel from Washington State University (primarily from the Irrigated Agriculture Research and Extension Center, at Prosser) and the U.S. Bureau of Reclamation (at Ephrata). Soils at the site were extremely sandy, and hence typified many of the new lands being developed or proposed for development in the Columbia Basin area. The project was designed to demonstrate that carefully controlled sprinkler irrigation of such soils was feasible, whereas furrow (rill) irrigation was impractical; and to conduct research into proper irrigation, fertilization, and management practices for such soils.

Site and Crop

The experimental site was on Farm Unit 30, Block 21, of the Columbia Basin Irrigation Project. The land was the property of the U.S. Bureau of Reclamation and had been leveled for the study. Sprinkler and furrow irrigation systems were installed prior to the first year of operation in 1969. The total experimental area was 13.6 hectares (33.5 acres), with 3.9 ha. used for sprinkler irrigation, 2.3 ha. for furrow irrigation, and the balance as border area. The latter was cropped to alfalfa in order to minimize boundary effects at the site.

Russet Burbank potatoes were used as the indicator crop. The experimental plot area was doubled in order to avoid potatoes following potatoes in successive years. Thus, part of the area could be maintained in fallow or an alternate crop while the remainder was in potatoes. This procedure helped minimize problems with Verticillium wilt and similar crop-specific diseases.

Experimental Design

Both furrow and sprinkler irrigation methods were investigated, using three irrigation rates, each replicated three times. Sprinkler plots were 24.4 x 24.4 meters, with furrow-irrigated plots being 10.4 x 122 meters (34 x 400 feet). Each of the latter generally was treated as two 10.4 x 61-meter sub-plots representing the head and tail portions of the field, respectively. A third set of plots was established in 1969 and 1971 to measure the effects of early-season sprinkler irrigation for wind erosion control on such sandy soils. The latter plots were 12.2 x 12.2 meters. Experimental variables were built around a split plot design, with fertilizer rates constituting the split plot and irrigation treatment constituting the whole plot. Internal borders separated the split plots.

The three sprinkler irrigation treatments used during the study period were based on the estimated minimum quantity of water (designated as the Q1 treatment) needed to just meet the evapotranspiration needs of the crop. This quantity was determined by the evaporation pan method (Jensen et al., 1961) as approximately 35% of the available moisture in the top 60 cm (2 feet) of soil plus estimated application losses for the sprinkler system used. Additional sprinkler-irrigation rates included 1.25 x Q1 and 1.50 x Q1 (designated respectively as the Q2 and Q3 rates) in 1969 and 1970, and 1.50 x Q1 and 1.80 x Q1 (designated respectively as the Q3 and Q4 rates) in 1971. The Q4 rate was added in 1971 to determine if the Q3 rate was approaching the maximum application rate for optimal potato production under the conditions of these experiments. Water was applied every other day in 1969 and daily in 1970 and 1971 at the indicated rates. Soil moisture levels were checked by gravimetric sampling. Treatments Q2, Q3, and Q4 were controlled by nozzle size-pressure relationships for the system so that a single length of time could be used for each irrigation application.

Fertilizer treatment sub-plots were four rows wide and 12.2 meters (40 feet) long, with fertilizer banded at planting time. Levels of nitrogen were varied in 112 kg/ha.(100 lb/a) increments between 112 and 560 kg N/ha., at 0, 110 or 560 kg P/ha., and at 0, 220 or 560 kg K/ha. Zinc was applied uniformly to all plots at a rate of 17 kg/ha. The 5 nitrogen application rates, plus supplementary P and K treatments, gave a total of 12 fertilizer treatments for this experiment.

The three furrow irrigation treatments used during the study period were based on the quantity of water (designated as the W1 treatment) required to wet the rows to mid-bed at mid-run for each irrigation. This was considered the minimum quantity of water that could be used for furrow irrigation at the site. This judgement was confirmed by the moisture stress that existed for many plots in the tail portion of the field at this water application rate. Additional furrow-irrigation rates each season included 2.0 x W1 and 3.0 x W1 (designated respectively as the W2 and W3 rates) on a time basis. Despite the water stress at the tail end of the field for the W1 treatment, excessive deep percolation occurred even with this treatment for plots at the head end of the field. Irrigation interval was four days in 1969, three days in 1970, and two days (on an alternate-furrow basis) in

1971. Fertilizer treatments were similar to those for the sprinkler experiments, except that only 4 nitrogen application rates were employed. Separate yield data were maintained, in order to permit measurement of fertility-moisture interactions related to differential leaching between the head and tail of the furrow-irrigated field.

In a third experiment at this location for the 1969 and 1971 seasons, the effect of early season sprinkler irrigation for wind erosion control was evaluated. Two irrigations of approximately 8 surface cm (3 surface in.) of water each (8.6 cm on May 20 and 8.1 cm on May 28) were applied between planting and plant emergence for these plots. Normal irrigation rates (comparable to the Q1 rates described above) then were applied during the regular crop season. In addition to assessing the degree of N leaching accompanying this practice, the use of urea and of nitrification retardants (e.g., N-Serve) was evaluated in an attempt to reduce nitrate formation during the early season period, and thereby reduce the potential for deep leaching of N.

General

A weather station was maintained at the site, monitoring wind speed and direction, pan evaporation, rainfall, and minimum and maximum daily temperatures. A winter wheat or sorghum cover crop was maintained on those plots not in use during a given season or portion thereof. Standard recommended applications of herbicides, fungicides, and insecticides were made throughout the growing season for control of plant pests. In a cooperative study, plant petioles were collected and analyzed throughout the growing season in order to assist fertilization recommendations for such sandy soils in the Columbia Basin. Crop yield data for the various treatments were collected as part of the cooperative study.

Soil and Water Sampling and Analyses

Porous ceramic extraction cups were used to collect samples of the soil solution for analysis throughout the growing season. The cups were standard (2.2 cm OD x 7.0 cm) tensiometer cups from Soil Moisture Equipment Co., Santa Barbara, California. They were connected to the soil surface with 0.5 cm nylon tubing, with Silastic bathtub calk used to produce a vacuum tight seal between tubing and extraction cup. The cups were buried at 30 cm depth intervals in the soils of 3 replicates each of the Q1, Q3, W1 and W3 irrigation treatments, at the 560 kg N/ha. fertilization rate. These data provided a measure of the quality of water percolating through the profile and/or moving laterally from the plots. Cups were placed to a maximum depth of 2.4 to 3.1 meters (8 to 10 ft.), depending upon the depth of underlying basalt bedrock in each plot. A portable vacuum pump was used to produce a vacuum of approximately 0.4 bar at each location, with a small butane tank used as a vacuum buffer volume on the manifold system for each set of cups. Soil solution extraction was terminated for each depth after 50-100 ml of solution had been obtained from the appropriate extraction cup or after 24 hours had elapsed since irrigation. Samples were stored in a refrigerator at ca. 4^{o} C until analysis.

All extraction cups were prewashed with 1 N HCl prior to installation, as recommended by Grover and Lamborn (1970). Dissolved inorganic N in the samples was measured with a steam distillation method employing MgO and Devarda's alloy (Bremner, 1965). Most of this nitrogen was in the nitrate form, as identified by combining the above steam distillation procedure with one employing MgO alone (Bremner, 1965) during the initial phase of the study. In addition, sample pH and electrical conductivity (EC) were measured with a standard laboratory pH meter and conductivity cell, respectively. Chloride was measured potentiometrically with a commercial chloridimeter (Cotlove, 1964).

Soil samples were collected at 30 cm (1 ft) depth increments on April 13, July 19, and September 24 from beneath those plots in which the extraction cups had been placed, as a check on soil solution measurements. Samples were collected with a King tube sampler during the season and either with a King tube or a hydraulic Giddings sampler at season's end. Samples were placed in 250 or 500 ml plastic cartons for transport the same day to the laboratory in Pullman. The samples then were frozen until they could be dried and analyzed. Drying was in a convective drying oven at 60^{o} C for 24 hours, with samples then ground to pass a 2 mm sieve and stored until analysis. Analyses were performed on 2:1 water:soil extracts, which were clarified by centrifugation after a 10-minute extraction period on a reciprocating shaker. Mechanical analysis (particle-size distribution) was run for some samples by the hydrometer procedure of Day (1965), using sodium hexametaphosphate (Calgon) as the dispersing agent.

Samples of input irrigation water and of surface runoff water from the furrow-irrigated plots were obtained periodically throughout the growing season. Additional analyses performed on these samples included turbidity in Jackson turbidity units (J.T.U.) with a Hach turbidimeter, soluble orthophosphate by an ascorbic acid modification of the Murphy and Riley (1962) method, and soluble polyphosphate by hydrolysis with H_2SO_4-HNO_3 in an autoclave for 30 minutes (American

Public Health Association, 1965), followed by analysis as for orthophosphate.

In addition to porous cup collection of soil solutions, piezometers (hollow pipes) were driven to ground water (2.4 to 3.1 meter depth) at several locations around the periphery of the study area, in order to monitor changes in ground water elevation and quality during the study period. Ground water sampling was not designed to reflect individual treatment effects, but rather to show major differences in ground water response between the sprinkler- and furrow-irrigated areas.

1972 SEASON

Work during the second year of the study was moved to the Othello Experimental Station, which is owned by Washington State University. The silt loam soils at this site are more typical of the older, developed areas of the Columbia Basin. Such soils have lower permeabilities and higher water-holding capacities than do the sandy soils studied during the first year of the project. Studies at this location were in cooperation with R. Kunkel and N. M. Holstad of the Department of Horticulture at Washington State University. A combination of ceramic soil solution extraction cups, and replicated soil samplings, was used to characterize the distribution and movement of fertilizer elements under various management regimes. Most experimental plots on the Othello station were either 2 or 4 rows wide, and approximately 9.2 meters (30 feet) long. Six replicates of most treatments were sampled, with results composited to produce the data tabulated in this report.

Furrow-irrigation Rate Experiment

In a replicated irrigation-rate, fertilization-rate experiment conducted during the 1972 growing season, a standardized, furrow-irrigation setting was employed to wet alternate sides of a given crop row every 2, 4, or 6 days (normal irrigation practice at the station involves an alternate-row interval of 2.5 days). Nitrogen fertilization rates of 220 and 460 kg N/ha. were applied to the plots in a banded application at the time of planting. Extraction cups were placed in all the experimental plots, with samples of extracted soil solution, as well as soil samples, taken at regular intervals throughout the growing season.

Tensiometers were used in the plot area of these and other experiments to provide estimates of the downward flux of water (quantity moving per unit of soil cross-sectional area) during the growing season. Portable tensiometers were used for similar measurements at off-station locations during the 1973 season. Sufficient data were collected from these sources to permit fairly reliable estimates of downward water flux from soil water contents alone at the Othello site.

Suspension Fertilizer Experiment

In fertilizer-rate experiments at Othello, suspension fertilizers (high-analysis mixtures of liquid and solid forms) were used as a concentrated source of nutrients, with treatments including banded, broadcast, sidedressed, and mixed applications at six rates ranging from 110 to 670 kg/ha. for each fertilizer element. Selected treatments from this experiment were monitored, using both soil samples and soil solution extraction cups, in replicated plots throughout the 1972 growing season. In addition, selected plots from the 1971 suspension fertilizer experiments at the Othello station were monitored to assess dissolved-N levels after the over-winter period and throughout the following summer and fall. The latter plots were seeded to ryegrass in August of 1972, with the ryegrass clumps covering about 25% of the soil surface at the time of the fall sampling.

Long-term Fertilizer Factorial

A key set of experiments at the Othello station was the long-term fertilizer plots, which had been maintained in differential fertilizer treatments ranging from 110 to 450 kg/ha. of each nutrient element annually since 1965, until 480 kg N/ha. was applied uniformly to the plot area in 1972. Both soil sampling and ceramic soil solution extraction cups were used to monitor these plots. The plots had been furrow-irrigated prior to the 1972 season, but were sprinkler-irrigated during the sampling period. Downward water flux estimates were made from tensiometers placed in the plots.

Slow-release Nitrogen Sources

In a final set of experiments monitored at the Othello station during the 1972 season, traditional N sources were compared with slow-release N formulations by replacing one-third of the traditional N source with one of three slow-release sources and monitoring soil solution dissolved-N levels and corresponding crop yields. Soil sampling was used exclusively for monitoring of these plots.

1973 SEASON

During the 1973 cropping season, soil sampling was expanded to assess fertilizer utilization and leaching in several growers' fields. These fields were arrayed in a 150 km (100 mile) arc extending from a location in the Horse Heaven Hills area south of Pasco and Kennewick to a location east of Moses Lake in the northern portion of the Columbia Basin. All locations were managed by the growers themselves, and thus provided an estimate of potential contamination of ground waters and drainage waters under "real-world" operating conditions. In addition, experiments were continued at the Othello Experimental Station of Washington State University.

Sampling of Growers' Fields

Two of the locations which were sampled used center-pivot sprinkler systems, and thus provided valuable data on the leaching occurring at different locations along the quarter-mile-long, moving booms of such systems. A replicated plot design laid out across the entire diameter of the circle provided data comparing fertilizer utilization and leaching as a function of relative boom location, fertilization rate, dry versus liquid fertilizer formulation, banded versus broadcast fertilizer application, and fumigated versus non-fumigated (chiseled only) potato seedbeds. In addition, a study of relative N leaching as a function of fertilization rate, using both standard and slow-release N fertilizer sources, was included at each location. As an aid to evaluating the feasibility and benefits of each treatment, yield data were obtained for all treatments at each location.

The two remaining growers' fields consisted of one furrow-irrigated location and one solid-set sprinkler-irrigated site. Treatments evaluated at these locations included fertilization rate, dry versus liquid fertilizer formulation, fumigated versus non-fumigated potato seedbed, banded versus broadcast fertilizer applications, and standard versus slow-release nitrogen sources. The locations provided additional data on fertilizer utilization and leaching under cropping conditions typical of those encountered in the central Washington area.

All locations were sampled extensively at the start of the growing season, approximately monthly during the growing season for selected plots, and again extensively at the conclusion of the growing season. Soil sampling was used exclusively to monitor these locations. Yield data were obtained from all plots to permit evaluation of the feasibility of various management practices. Data from these locations also supplemented data from the two extensively-studied sites (Block 21 and the Othello station) in a comparison of plot-to-plot soil variability under a wide variety of experimental conditions.

Sampling at the Othello Station

In addition to the above experiments, further experiments were conducted in 1973 on the Othello Experimental Station. One experiment involved a detailed comparison of yields and of utilization and leaching of N for three standard and three slow-release N fertilizer sources. A second experiment evaluated fertilizer utilization at different fertilization rates for sprinkler-irrigated potatoes harvested after variable growing periods, to simulate potato production for different portions of the fresh and processing markets. Still another experiment involved evaluation of yields and fertilizer leaching for differentially-fertilized plots irrigated at three different sprinkler-irrigation rates (estimated optimum, 0.75 x optimum, and 1.50 x optimum) and fertilized at rates ranging from 110 to 670 kg N/ha. Irrigation scheduling was based upon a combination of micro-climatological measurements and weighing lysimeters maintained by G. S. Campbell, W. H. Gardner, and C. Calissendorff of WSU. A final experiment at this location involved assessment of yields and of N leaching in plots where a majority of the fertilizer N was applied in soluble form through the sprinkler line at two rates, and at intervals of either two, four, or six weeks, during the final 2/3 of the growing season. This was done to see if lowered soil solution N values could be maintained through "nitrogation" (sprinkler application of fertilizer N), while still giving high-level production of high-quality tubers.

The 1973 cropping season also was used to collect supplemental data on water quality effects from irrigation agriculture, including additional monitoring of typical irrigation waters and tailwaters for furrow-irrigated plots at the Othello station, and evaluation of sediment yield from these same plots. An extensive comparison of petiole N values and of corresponding soil N levels was initiated by a Peruvian student (C. P. Diaz) who assisted with much of the field program for 1973. This study was designed to aid in establishing necessary plant and soil N values which permit both economical potato production and minimal leaching of fertilizer N. Yearly soil test analyses of surface soils from the long-term fertilizer factorial experiment (described above) were also evaluated in 1973, to determine the extent of lateral surface transport of P and K during furrow irrigation of these plots.

1974 SEASON

Much of the research effort during the final year of study revolved around completion of accumulated analyses from samplings of previous seasons, and summarization and evaluation of accumulated experimental data. Hence, the field program for 1974 was returned to the Othello station and reduced considerably in scope. Most experimental work was concentrated on two small-scale experiments at this location.

Potato Yields at Constant Petiole Nitrate-N Levels

A standard approach to nitrogen management in the Columbia Basin and elsewhere has been the monitoring of plant petiole nutrient levels, with application of nitrogen through the sprinkler line whenever the petiole N or nitrate-N values approach a specified "critical" level. In order to obtain data on the reliability of this approach, three varieties of potatoes were grown in sprinkler-irrigated plots on the Othello station, with N applied through the sprinkler line in an attempt to maintain petiole nitrate-N levels of 2,500, 5,000, 10,000, or 20,000 ppm throughout the growing season. Fertilization through the lines was begun on June 13, after 90 kg N/ha. which was banded at the time of planting was largely depleted. Fertilization was with liquid ammonium nitrate (20% N). Petiole samples were taken weekly from June 12 to September 18, or until suitable petioles were no longer being produced by the vines. All plots were replicated 6 times.

Effects of Di-syston Rates on Potato Yields

In another 1974 experiment at the Othello station, two potato varieties were treated with 4.5, 9, 18, or 36 kg/ha. (actual) Di-syston (a systemic insecticide), with the dual goal of monitoring decreases in Di-syston levels throughout the growing season and of determining the yields from potato plots exposed to various Di-syston rates. One portion of the experiment consisted of a sprinkler-irrigated field having superimposed N fertilization rates of 220 or 450 kg N/ha. A second portion consisted of a furrow-irrigated field fertilized at a rate of 450 kg N/ha., but with superimposed plant populations of 37,000 or 57,000 plants per hectare. Soil sampling was conducted monthly and consisted of a constant volume of soil (including each of the two fertilizer bands for a single potato row) from each sampled plot. Di-Syston analyses were carried out by gas chromatography following hexane extraction, using a modification of the procedure of Clapp (1975). Samples of soil from the fertilizer bands also were used to follow changes in EC, pH, chlorides, and dissolved inorganic N within the band during the growing season.

Nitrogen Movement Associated with Minimum Tillage Potato Production (Preliminary)

In a final sampling program for the 1974 season, soil samples were collected in early spring from plots where potatoes were being planted directly in the stubble of a previously-fertilized winter wheat or ryegrass cover crop. This management approach, designed to minimize both wind erosion and traffic compaction in potato fields of the Columbia Basin area, is being tested extensively on the Othello station at the present time. Samples were taken with a King tube by 30 cm- or 60 cm-increments to the depth of the underlying caliche layer. The samples were placed in plastic cartons, transported to Pullman, and then handled and analyzed as described above for other soil samples collected during the study period.

SECTION V

RESULTS AND DISCUSSION

1971 SEASON

Experiments for the 1971 season were conducted at the sandy Block 21 experimental site. As for previous years of the Block 21 study (1969 and 1970), the data demonstrated that extensive leaching of N from the soil profile occurred when such soils were furrow-irrigated, or when they were sprinkler-irrigated at excessive rates. However, carefully managed sprinkler-irrigation generally maintained fertilizer N in the upper part of the soil profile, where it could be taken up by a deep-rooted cover crop or by subsequent crops in the rotation.

Climatological and Water Application Data

Climatological data for the Block 21 experimental site are summarized by month and growing season in Table 1. Typical features of growing seasons in the area are steady winds (of greater intensity during the late spring and early fall portions of the growing season), generally-cool late springs and early summers, and hot, dry mid-summer months. Distinctive for the 1971 season was the prolonged (28 day) period of greater-than 32° C (90° F) temperatures in late July and early August, which began just 2 days after the daily minimum temperature had dropped to 4° C (39° F). Wind during this season ranged from a high of 870 km/day on April 12 to a low of 18 km/day on August 20. The 1970 and 1969 seasons exhibited hotter and drier Junes than did the 1971 season, as reflected by both the temperature and evaporation data. Another distinctive feature of the climatological data was the low evaporative demand in September of 1970, reflecting the early killing frost of this season.

Water application data for the Block 21 experimental site are summarized by month and growing season in Table 2, with corresponding runoff data from the furrow-irrigated plots summarized in Table 3. An average of only 67 to 76 surface cm (2.2 to 2.5 surface feet) of irrigation water was required for potato production at this site under the conditions of most efficient irrigation management (Q1 sprinkler treatment), whereas an average of 290 to 445 surface cm of water was required for the lowest rate of furrow irrigation. The enhanced potential for nutrient leaching from such soils during fur-

Table 1. SUMMARIZED CLIMATOLOGICAL DATA, 1971-1969, BLOCK 21 SITE

Parameter	April	May	June	July	Aug.	Sept.	Total or Wtd. Avg.
1971 Season (April 6-Sept. 20)							
Total precipitation (cm)	0.43	1.68	3.53	0.64	0.28	2.16	8.71
Total evaporation (cm)	13.9	22.6	22.1	31.1	25.0	14.1	128.8
Average minimum temperature (° C)	2	7	7	13	12	5	8
Average maximum temperature (° C)	18	24	23	31	32	23	26
Average wind (km/day)	245	253	182	148	93	249	190
1970 Season (April 7-Sept. 11)							
Total precipitation (cm)	2.11	0.23	0.76	0.33	0.00	0.41	3.84
Total evaporation (cm)	12.8	21.0	29.3	28.1	28.8	6.0	125.9
Average minimum temperature (° C)	2	6	12	12	12	7	9
Average maximum temperature (° C)	16	22	29	30	31	23	26
Average wind (km/day)	285	190	193	127	148	163	182
1969 Season (May 5-Sept. 16)							
Total precipitation (cm)	-	1.35	1.22	0.00	0.00	0.00	2.57
Total evaporation (cm)	-	-	-	13.9[a]	22.9	12.3	49.1
Average minimum temperature (° C)	-	7	11	10	8	7	9
Average maximum temperature (° C)	-	26	29	31	28	28	29
Average wind (km/day)	-	174	237	116	146	219	174

[a]Measurements begun July 19.

Table 2. MONTHLY WATER APPLICATIONS, BLOCK 21 SITE
(surface cm of water)

Experiment[a]	April	May	June	July	Aug.	Sept.	Total
1971 Season (April 6-Sept. 20)							
Early excess	0.0	20.2	12.7	26.4	23.1	3.2	85.5
Q1	0.0	3.3	11.5	26.6	23.0	3.3	67.7
Q3	0.0	5.1	17.5	40.7	35.6	5.0	104.0
Q4	0.0	6.0	20.9	48.5	42.5	6.0	124.0
W1	0.0	34.1	71.2	96.4	107.3	29.0	338.0
W2	0.0	36.6	94.1	193.0	210.0	45.4	579.0
W3	0.0	38.2	119.7	296.9	330.6	70.1	855.6
1970 Season (April 7-Sept. 11)							
Q1	1.6	2.9	16.9	26.3	22.9	4.6	75.1
Q2	2.0	3.7	21.2	32.9	28.7	5.7	94.2
Q3	2.4	4.4	25.5	39.5	34.5	6.9	113.2
W1	8.2	19.3	97.4	139.1	140.5	40.3	444.9
W2	10.1	22.2	166.0	227.2	253.1	69.4	748.1
W3	8.6	21.1	251.4	371.2	393.1	39.7	1161.3
1969 Season (May 5-Sept. 16)							
Early excess	0.0	9.9	21.5	27.2	24.9	6.4	89.9
Q1	0.0	3.5	14.7	26.2	24.8	5.8	75.1
Q2	-	-	-	-	-	-	-
Q3	0.0	3.5	21.6	38.2	36.9	8.6	108.9
W1	0.0	0.0	62.9	94.5	95.5	35.1	288.0
W2	0.0	0.0	140.7	192.9	170.5	58.2	562.4
W3	0.0	0.0	157.4	253.5	237.8	82.2	730.8

[a]Early excess = Q1 + two early-season applications for wind erosion control; Q1, Q2, Q3, and Q4 = sprinkler application rates of optimum, 1.25 x optimum, 1.50 x optimum and 1.80 x optimum, respectively; W1, W2, and W3 = furrow application rates of minimum, 2.0 x minimum, and 3.0 x minimum, respectively.

Table 3. SUMMARIZED FURROW RUNOFF DATA, BLOCK 21 SITE

a. Expressed as surface centimeters of water

Experiment[a]	April	May	June	July	Aug.	Sept.	Total or Wtd. Avg.
W1 (1971)	0.0	1.0	4.2	5.9	6.8	2.1	19.9
W2 (1971)	0.0	0.8	5.9	16.9	23.1	4.3	51.1
W3 (1971)	0.0	1.4	8.4	24.4	36.9	7.2	78.3
W1 (1970)	0.3	2.6	11.9	14.9	9.7	2.5	41.9
W2 (1970)	0.2	2.0	42.8	50.2	30.4	7.1	132.7
W3 (1970)	0.1	2.2	45.7	68.4	38.2	10.7	165.3
W1 (1969)	0.0	0.0	4.5	5.8	5.8	1.9	18.0
W2 (1969)	0.0	0.0	7.5	16.8	15.9	3.4	43.6
W3 (1969)	0.0	0.0	9.7	19.1	18.0	5.1	51.8

b. Expressed as a percentage of the applied water

Experiment	April	May	June	July	Aug.	Sept.	Total or Wtd. Avg.
W1 (1971)	0.0	2.9	5.9	6.1	6.3	7.3	5.9
W2 (1971)	0.0	2.3	6.3	8.8	11.0	9.5	8.8
W3 (1971)	0.0	3.6	7.0	8.2	11.2	10.2	9.2
W1 (1970)	3.1	13.3	12.2	10.7	6.9	6.3	9.4
W2 (1970)	1.8	9.2	25.8	22.1	12.0	10.2	17.7
W3 (1970)	1.2	10.3	18.2	18.4	9.7	9.2	14.2
W1 (1969)	0.0	0.0	7.1	6.2	6.0	5.3	6.2
W2 (1969)	0.0	0.0	5.4	8.7	9.3	5.8	7.8
W3 (1969)	0.0	0.0	6.1	7.5	7.6	6.1	7.1

[a] W1, W2, and W3 = furrow application rates of minimum, 2.0 x minimum, and 3.0 x minimum, respectively.

row irrigation or poorly managed sprinkler irrigation is evident from this comparison. Because of the high infiltration rates of soils at the site, runoff generally was less than 6 to 9 percent of the total water applied to furrow-irrigated plots, even after irrigation furrows had been carefully shaped and packed to minimize early-season percolation losses during the 122 meter (400 ft) irrigation run. The marked increase in water application and runoff in 1970 is ascribed to the increased frequency of irrigation compared to the 1969 season. Adoption of the alternate-furrow irrigation approach substantially lowered water application and runoff values for the 1971 season.

Yield Data

Data on total yield of potatoes at the Block 21 site are summarized in Table 4. Corresponding values for percent U.S. No. 1 tubers are given in Table 5. Yield data for the 1970 season are considered unreliable, because of a severe infestation of leafroll at the site. The infestation had a particularly marked effect on potato quality for the furrow-irrigated plots.

Highest total yields generally were obtained for the high-rate Q3 sprinkler irrigation treatment, despite substantial leaching of fertilizer N. The low-rate Q1 and Q2 sprinkler treatments apparently produced moisture stress in some plots under the windy Columbia Basin conditions, and the high-rate Q4 treatment produced excessive leaching of N. The latter effect was evident for the lower N-fertilization rates in 1971. Application of early excess sprinkler irrigation reduced yields at the lowest N-fertilization rate, but sidedressed and sprinkler-applied N added later in the growing season restored high yields for this treatment. Because all N was not banded at the time of planting in the early-excess experiment, results are not strictly comparable with those for standard sprinkler-irrigated plots.

Total yields were substantially lower for the furrow-irrigated plots. Average yields generally were somewhat higher for the tail portion of the field (61-122 meters of run), although differences in yield between the two portions of the field were not large. Yields of furrow-irrigated plots generally were lowest in the head portion of the field for the W3 (high-rate furrow) treatment, due to the high leaching produced. However, the same treatment generally produced the highest yields in the tail portion of the field, due to decreased moisture stress.

Yields of U.S. No. 1 tubers (Table 5) were substantially higher for the sprinkler-irrigated plots than for their furrow-irrigated counterparts. Values commonly were highest at intermediate nitrogen application rates, with the depressing effect of high levels of N on tuber quality particularly evident at the lower water application rates and in the tail portion of the furrow-irrigated field.

Table 4. TOTAL YIELD DATA, BLOCK 21 SITE
(quintal/hectare)[a]

Treatment[b]	Nitrogen application rate (kg N/hectare) 110	220	340	450	560
1971 Season					
Early excess	426	551	553	600	-
Q1	516	495	587	521	590
Q3	450	536	598	603	644
Q4	417	493	591	562	626
W 1 (0-61m)	-	251	329	314	349
W 2 (0-61m)	-	227	289	253	293
W 3 (0-61m)	-	231	284	283	314
W 1 (61-122m)	-	241	347	237	311
W 2 (61-122m)	-	242	300	228	264
W 3 (61-122m)	-	246	358	311	278
1970 Season					
Q1	452	465	529	458	472
Q2	405	487	549	514	438
Q3	461	536	531	554	516
W 1 (0-61m)	-	352	363	351	419
W 2 (0-61m)	-	316	423	358	358
W 3 (0-61m)	-	245	278	382	233
W 1 (61-122m)	-	419	448	355	305
W 2 (61-122m)	-	412	426	420	379
W 3 (61-122m)	-	448	508	441	376
1969 Season					
Early excess	412	515	586	609	627
Q1	376	508	520	560	584
Q2	392	515	531	566	587
Q3	450	494	508	580	589
W 1 (0-61m)	-	383	479	411	457
W 2 (0-61m)	-	321	381	368	414
W 3 (0-61m)	-	310	345	450	435
W 1 (61-122m)	-	377	401	372	430
W 2 (61-122m)	-	379	475	407	417
W 3 (61-122m)	-	396	484	459	488

[a]Divide by 1.12 to convert values to cwt/acre.

[b]Early excess = Q1 + two early-season applications for wind erosion control; Q1, Q2, Q3, and Q4 = sprinkler application rates of optimum, 1.25 x optimum, 1.50 x optimum and 1.80 x optimum, respectively; W1, W2, and W3 = furrow application rates of minimum, 2.0 x minimum, and 3.0 x minimum, respectively.

Table 5. TUBER QUALITY DATA, BLOCK 21 SITE
(percent U.S. No. 1's)

Treatment[a]	Nitrogen application rate (kg N/hectare) 110	220	340	450	560
1971 Season					
Early excess	82.3	85.4	84.6	81.2	-
Q1	84.4	84.4	81.9	77.0	70.5
Q3	78.7	84.5	83.8	76.5	71.4
Q4	75.9	83.5	86.3	81.2	75.1
W1 (0-61m)	-	65.5	78.8	70.9	58.5
W2 (0-61m)	-	65.0	61.1	61.6	55.6
W3 (0-61m)	-	67.7	58.1	68.8	67.0
W1 (61-122m)	-	57.5	53.2	56.0	46.9
W2 (61-122m)	-	61.9	56.9	57.9	47.3
W3 (61-122m)	-	65.7	60.3	55.4	44.8
1970 Season					
Q1	68.5	67.2	66.8	63.9	59.7
Q2	67.5	70.1	65.3	66.5	59.6
Q3	63.6	69.6	60.9	64.8	57.3
W1 (0-61m)	-	33.6	36.8	32.7	27.1
W2 (0-61m)	-	29.3	19.7	22.1	14.8
W3 (0-61m)	-	21.0	26.2	31.2	17.2
W1 (61-122m)	-	26.1	13.2	15.8	8.8
W2 (61-122m)	-	35.1	37.4	24.1	31.1
W3 (61-122m)	-	38.6	22.1	31.1	26.3
1969 Season					
Early excess	88.0	80.7	58.3	63.1	66.4
Q1	85.5	76.4	67.6	76.8	70.2
Q2	89.5	87.9	90.0	83.8	82.9
Q3	91.5	89.0	87.9	88.5	84.6
W1 (0-61m)	-	59.0	55.3	58.2	35.3
W2 (0-61m)	-	67.0	59.1	50.2	48.5
W3 (0-61m)	-	65.0	67.6	56.2	49.3
W1 (61-122m)	-	48.3	37.7	35.3	17.9
W2 (61-122m)	-	61.3	35.9	38.6	36.0
W3 (61-122m)	-	55.4	40.0	43.0	41.5

[a]Early excess = Q1 + two early-season applications for wind erosion control; Q1, Q2, Q3, and Q4 = sprinkler application rates of optimum, 1.25 x optimum, 1.50 x optimum and 1.80 x optimum, respectively; W1, W2, and W3 = furrow application rates of minimum, 2.0 x minimum, and 3.0 x minimum, respectively.

Soil Solution Dissolved Inorganic Nitrogen Values

Summarized results of the extraction cup sampling for soil solution N values in 1971 and 1970 are presented in Table 6. No extraction cup sampling was carried out at the site in 1969. Complete extraction cup data for the two seasons, including values for electrical conductivity (EC) and dissolved chloride (Cl) as well, are presented in Appendix Tables A-1 to A-9. Appendix data for the 1971 season are the average of 3 replicates, whereas data for the 1970 season represent individual sites, and thus more clearly demonstrate the sampling problems encountered.

High dissolved -N concentrations (primarily nitrate-N) were observed in soil solutions extracted from all plots during the growing season (Tables 6, A-3, A-6, and A-9). Values in excess of 100 mg/liter (and over 1,000 mg/liter for individual samples) were not uncommon. Values of 20-60 mg/liter at the basalt interface underlying the field were normal when adequate N was present in the soil profile for potato production.

Good water management at this sandy site minimized leaching of N (Table 6). Most N was leached from the soil profile by early August for the high-rate furrow plots. Appreciable N still remained in the lower profile of the low-rate furrow plots by mid-August of 1971. The high-rate sprinkler plots similarly were depleted of N throughout much of the soil profile by early September, although they retained considerable N at the time of the August sampling. Fertilizer N remained primarily in the 60- to 120-cm soil zone throughout the crop year for the low-rate sprinkler plots. It should be remembered when interpreting the data that high concentrations of solutes may be present in the soil mass between extraction cup depths on a given sampling date, although not measured by the extraction cups on that date. Another problem is that all cups may not extract solution on a given date, so that different sample populations may exist at different sampling times. This effect was particularly pronounced for our studies in 1971, when ceramic cups were purchased from an alternate supplier with poorer quality control than the Santa Barbara supplier.

The values in Table 6 represent means of three replicates, so examination of data from individual locations (e.g. Tables A-4 to A-9) is necessary in some cases to show definite leaching trends at high water application rates. Such individualized examination also tends to verify that the solute peaks were relatively static for the low-rate

Table 6. AVERAGE DISSOLVED INORGANIC N, SOIL SOLUTION, BLOCK 21 SITE (mg/liter)

a. 1971 Season

Treatment	Depth	May 5	June 11	July 8	Aug. 12	Sept. 9
Low rate sprinkler (Q1)	Top 120 cm	16	60	122	255	513
	Lower Profile	20	26	100	200	93
High rate sprinkler (Q3 = 1.5 x Q1)	Top 120 cm	16	29	211	153	93
	Lower Profile	59	63	52	85	23
Low rate furrow (W1)	Top 120 cm	56	195	512	85	26
	Lower Profile	206	20	162	123	12
High rate furrow (W3 = 3 x W1)	Top 120 cm	23	390	77	16	2
	Lower Profile	9	5	91	9	3

b. 1970 Season

Treatment	Depth	April 20	June 4	July 3	Aug. 5	Sept. 4
Low rate sprinkler (Q1)	Top 120 cm	64	91	24	213	82
	Lower Profile	115	39	39	25	62
High rate sprinkler (Q3 = 1.5 x Q1)	Top 120 cm	261	181	381	110	15
	Lower Profile	30	33	20	235	42
High rate furrow (W3 = 3 x W1)	Top 120 cm	143	229	58	1	1
	Lower Profile	23	27	5	1	3

sprinkler plots. A major problem which must be solved before extraction cups can be used to provide valid estimates of solute leaching in non-tiled areas is the between-site variability in leaching rates. Even small variations in leaching rate cause solute peaks to arrive at a specific depth at different times at different sites. Part of the variability in absolute solute concentrations is also due to variations in lateral placement of extraction cups with respect to the fertilizer band.

Table 7. DISSOLVED INORGANIC N, PAIRED LOCATIONS, BLOCK 21 SITE[a]

(mg/liter)

Location	Depth, cm	June 11	July 8	Aug. 12	Sept. 9
Plot 1, #1	180	-	4	3	19
Plot 1, #2	180	18	14	13	7
Plot 2, #1	180	83	30	17	13
Plot 2, #2	180	25	19	17	8
Plot 3, #1	180	24	30	106	10
Plot 3, #2	180	9	8	323	56
Plot 4, #1	240	16	41	70	94
Plot 4, #2	240	34	42	41	36

[a]Extracted Solutions, high-rate (Q3) sprinkler plots, 1971 season.

An example of sampling variability in our studies is given in Table 7, where dissolved-N concentrations are reported for cups placed at the same depth within the same experimental plots (approximately 6 meters apart). Note the extremes encountered, such as the variations on June 11 for plot 2, on August 12 for plot 3, and on September 9 for plot 4. Such data point out the hazard of indiscriminately extrapolating from a few extraction cups to an entire irrigated field.

Tables 8 and 9 give the results of a 1971 soil sampling program designed to reduce the problems associated with extraction cup sampling of the soil solution. Results are for nitrate-N only, although such results normally differ appreciably from values for total dissolved-N only for the surface 30 cm of soil. The results are expressed on a weight basis as ppm of the soil mass, and hence must be multiplied by a factor of 6 to 8 to produce values more truly comparable with the soil solution values discussed above. The values generally were less variable than the extraction cup data, but were still highly variable (e.g., Table 8: June 11, high rate, and July 19, high rate; Table 9: June 11, low rate, July 19, low rate, and September 24, low rate). Such variability could be explained partially for the furrow plots as variations in the movement of the wetting front during irrigation (e.g., Table 9, reversal of positions of replicates 2 and 3 on July 19 compared to their

Table 8. SOIL NITRATE N, SPRINKLER-IRRIGATED PLOTS, BLOCK 21 SITE[a]

(ppm, soil basis)

Depth, cm	Q1 application rate[b] Rep 1	Rep 2	Rep 3	Q3 application rate Rep 1	Rep 2	Rep 3
April 14						
0- 60	61.2	66.5	18.0	7.9	17.3	43.8
60-120	2.4	1.9	3.7	1.2	3.1	3.8
120-180	13.5	10.7	6.1	1.1	1.7	12.6
180-240	8.7	3.9	11.5	1.6	8.6	11.0
Average	21.5	20.8	9.8	3.0	7.7	17.8
June 11						
0- 60	100.5	99.0	70.6	32.4	114.6	89.3
60-120	3.3	3.6	1.6	1.2	1.8	1.5
120-180	44.7	26.7	9.6	0.8	2.1	2.8
180-240	17.6	6.7	15.5	0.7	7.7	13.8
Average	41.5	34.0	24.3	8.8	31.6	26.9
July 19						
0- 60	109.8	107.6	36.2	0.5	14.3	256.5
60-120	6.5	5.7	1.7	1.6	51.7	61.8
120-180	34.8	28.4	9.0	19.6	8.0	13.8
180-240	13.8	7.3	15.4	1.3	4.0	5.1
Average	41.2	37.3	15.6	5.8	19.5	84.3
Sept. 24						
0- 60	19.1	14.1	34.6	0.7	1.0	4.1
60-120	19.8	54.1	13.7	1.0	4.2	14.0
120-180	11.5	11.0	6.6	1.1	8.7	15.3
180-240	14.8	15.8	12.3	0.7	30.8	22.1
Average	16.3	23.8	16.8	0.9	11.2	13.9

[a]High nitrogen (560 kg N/ha.), banded application, 1971 season.
[b]Q1 = low rate sprinkler application, Q3 = high rate sprinkler application (= 1.5 x Q1).

Table 9. SOIL NITRATE N, FURROW-IRRIGATED PLOTS, BLOCK 21 SITE[a]

(ppm, soil basis)

Depth, cm	W1 application rate[b]			W3 application rate		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
April 14, row						
0- 60	19.2	15.7	35.4	9.4	34.7	14.0
60-120	1.7	15.5	6.4	5.2	11.4	2.0
120-180	3.7	12.0	30.8	6.8	6.5	1.1
180-240	12.9	2.4	10.0	1.8	2.9	1.0
Average	9.4	11.4	20.7	5.8	13.9	4.5
June 11, row						
0- 60	32.3	136.2	98.0	91.2	98.5	67.1
60-120	16.3	34.7	124.2	5.7	28.8	16.3
120-180	1.3	11.7	18.9	6.4	5.4	2.5
180-240	5.8	8.8	6.0	2.3	26.8	0.7
Average	13.9	47.9	61.8	26.4	39.9	21.7
July 19, row						
0- 60	1.2	93.7	13.4	44.9	3.1	22.7
60-120	21.8	24.0	8.9	12.5	1.8	7.6
120-180	12.7	49.7	8.2	9.0	6.2	7.1
180-240	3.0	74.8	5.8	9.4	4.5	6.0
Average	9.7	60.6	9.1	19.0	3.9	10.9
Sept. 24, row						
0- 60	7.3	5.1	51.9	16.3	3.2	23.9
60-120	1.9	2.2	5.7	2.9	2.4	3.3
120-180	0.8	4.5	9.0	1.6	1.2	2.5
180-240	3.5	2.3	7.2	1.3	0.8	3.0
Average	3.4	3.5	18.5	5.5	1.9	8.2
Sept. 24, furrow						
0- 60	0.9	5.7	0.9	2.3	2.3	20.7
60-120	0.6	1.0	1.0	0.8	0.5	4.0
120-180	0.8	1.0	0.9	0.4	0.4	0.9
180-240	0.5	0.5	0.4	0.4	0.7	2.5
Average	0.7	2.1	0.6	1.0	1.0	7.0

[a]High nitrogen (560 kg/ha.), banded application, 1971 season.
[b]W1 = low rate furrow application, W3 = high rate furrow application (= 3 x W1).

positions on June 11). However, such an explanation is invalid for the sprinkler-irrigated plots. An assessment of this effect was attempted in subsequent years, by comparing values for banded and broadcast fertilizer applications and different water application methods.

Table 10 summarizes data on the N concentrations of solutions extracted from plots fertilized with the standard N source for this study (ammonium nitrate) and for plots to which a microbial nitrification inhibitor (N-Serve) was applied along with either an ammonium nitrate (NH_4NO_3) or urea nitrogen source. Dissolved inorganic-N levels in excess of 200 mg/liter were observed for the NH_4NO_3 plots, and fertilizer N had been leached to a considerable depth by the 13th week of the study. Application of N-Serve with the NH_4NO_3 lowered the maximum N concentrations considerably, and led to the preservation of considerable dissolved-N in the upper part of the profile even after 13 weeks of leaching. The combination of urea plus N-Serve lowered the maximum dissolved-N concentrations even more, and apparently led to release of fertilizer N at a rate less than the maximum plant uptake rate, so that appreciable quantities of dissolved-N never accumulated in the profile during the experiment.

In addition to soil solution extraction, ground water samples were collected from piezometers located around the perimeter of the study area. Of the eight piezometer locations, only three accumulated sufficient water for measurement and sampling during the irrigation season. These locations were in the vicinity of the furrow-irrigation plots. Free-flowing water was not observed in these piezometers until the first of July, with dissolved-N values averaging 3.8 mg/l at the edge of the furrow plots, and between 20 and 30 mg/l within the plot boundaries. This substantiates early indications of a significant leaching of N from the furrow-irrigated plots.

Sampling of Irrigation and Runoff Waters

Samples of irrigation water and surface runoff water (tailwater) from the furrow-irrigated plots at the Block 21 experimental site were collected during the 1970 and 1971 seasons. Results of their analyses are given in Table 11. In addition, complete chemical characterization of major constituents in the irrigation water was carried out for the 1970 samples. These analyses revealed an average of 32% Na, 3% K, 28% Ca, and 37% Mg (on an equivalent basis) for the major cations, and 9% CO_3, 54% HCO_3, 27% SO_4, 9% Cl, and 1% NO_3 for the major anions. Irrigation water composition did not vary appreciably during the season. Runoff water quality also was relatively constant, although N levels of the runoff water increased substantially near the

Table 10. DISSOLVED INORGANIC N, NITRIFICATION RETARDANT PLOTS, BLOCK 21 SITE[a]

(mg/liter)

Fertilizer Treatment	Depth, cm	Weeks after fertilizer application				
		1	3	5	9	13
NH_4NO_3	60	--	40	220	4	4
	120	10	9	18	170	5
	180	8	19	24	215	33
	240	14	20	--	48	92
NH_4NO_3 + N-Serve	60	40	25	12	2	30
	120	12	--	--	--	130
	180	54	40	18	17	10
	240	68	70	34	2	14
Urea + N-Serve	60	7	--	80	--	--
	120	18	15	26	13	6
	180	21	14	13	8	13
	240	57	33	9	36	12

[a] 1971 season, irrigated at the high-rate (Q3) sprinkler-application rate, fertilized at a rate of 340 kg N/ha., microbial nitrification retardant = N-Serve.

Table 11. IRRIGATION WATER AND RUNOFF WATER ANALYSES, BLOCK 21 SITE

Sampling Date		pH	EC, µmho/cm	Cl, mg/liter	Inorganic N, mg/liter	Turbidity, JTU
Irrigation waters						
	4-20-70	-	531	19	1.4	-
	5-26-70	-	482	18	0.0	-
	8-20-70	-	435	16	1.0	-
	7- 1-71	8.6	465	18	4.1	-
Runoff waters						
W1[a]	4-17-70	8.4	286	11	0.9	501
	6- 4-70	8.1	504	17	1.3	406
	7-21-70	8.2	443	18	0.7	-
	6-11-71	8.5	479	16	0.8	119
	7- 1-71	8.4	468	17	4.2	-
	7- 8-71	8.3	486	18	2.7	37
W2	4-17-70	8.5	434	18	0.9	430
	6- 4-70	8.0	509	17	0.5	180
	7-21-70	-	-	-	-	-
	6-11-71	8.6	467	17	0.8	89
	7- 1-71	-	-	-	-	-
	7- 8-71	-	-	-	-	-
W3	4-17-70	8.5	448	19	1.4	595
	6- 4-70	8.2	496	17	1.6	104
	7-21-70	8.3	440	18	0.5	-
	6-11-71	8.6	480	17	1.9	103
	7- 1-71	8.4	468	18	4.3	-
	7- 8-71	8.2	486	18	2.5	20

[a]W1 = low-rate furrow plots, W2 = 2 x W1, W3 = 3 x W1.

end of the 1971 season, and water turbidity decreased markedly within each season and between 1970 and 1971. The latter effect may be attributed to the greater water application and runoff rates for the 1970 season (Tables 2 and 3). Turbidity values generally were high enough to suggest major problems in reducing suspended solids or turbidity values to commonly-proposed return flow standards. Values for suspended solids (in mg/liter) averaged about 3 times the turbidity values (in JTU). This high relation probably reflects the relatively coarse nature of the suspended materials in runoff waters from this site.

Soil Solution Sampling Variability

Summarized means and standard deviations for soil solutions collected at three specified times during the 1971 season at the Block 21 experimental site are given in Table 12. Mean concentration values between the upper and lower profile substantiate the leaching trends for low and high irrigation rates, as inferred previously. The soil sampling values permitted an additional comparison, in which the dissolved-N from the surface 30 cm of soil could be deleted to produce values for the 30- to 120-cm depth only. These values demonstrated the high levels of N that remained in the 0 to 30-cm depth throughout the irrigation season for many of the treatments. Extraction cups had been placed at the 30-cm depth in all plots for the 1970 season, but they rarely produced soil solution samples because of the rapid drainage from this portion of the root zone. The increase in dissolved-N for samples from the surface 120 cm of soil between early season and mid-season probably reflected the conversion of additional ammonium to the soluble nitrate form during the intervening period.

Standard deviation values for the 1971 season averaged 74% of the mean values for the extraction cup data, and 78% of the mean values for the soil sampling data. Thus, there appeared to be little to choose between the two sampling approaches. This was surprising, for the soil sampling data included the entire soil profile, rather than the relatively-few points in the soil profile which were sampled by the extraction cup approach. Thus, solute peaks between extraction cup depths should not have been detected. It may be that the relatively large sample volumes extracted from this coarse-textured soil represented a rather sizable volume of soil, and thus provided an integrating effect not unlike the soil sampling approach.

Variability was only slightly less for the sprinkler-irrigated plots than for the furrow-irrigated plots (74% of the mean vs 79%) and was only slightly higher for the upper profile than for the lower

Table 12. AVERAGED VALUES FOR DISSOLVED INORGANIC N, BLOCK 21 SITE (mg/liter)

Treatment	Depth, cm	5-1 to 6-30 Mean	5-1 to 6-30 Std. Dev.	7-1 to 8-15 Mean	7-1 to 8-15 Std. Dev.	8-16 to 9-16 Mean	8-16 to 9-16 Std. Dev.
a. Extraction cup data							
Q1 (Low rate sprinkler)	0-120	47	20	192	182	438	420
	120+	28	16	119	120	101	38
Q3 (High rate sprinkler)	0-120	62	8	177	196	81	120
	120+	65	19	98	109	23	15
W1 (Low rate furrow)	0-120	174	141	241	238	35	38
	120+	51	27	154	60	11	12
W3 (High rate furrow)	0-120	330	95	69	52	2	1
	120+	31	36	45	23	3	2
b. Soil sampling data							
Q1 (Low rate sprinkler)	0-120	379	179	666	332	274	170
	30-120	33	15	51	27	257	180
	120+	67	41	86	49	68	21
Q3 (High rate sprinkler)	0-120	398	239	821	1208	36	37
	30-120	29	16	663	873	38	39
	120+	44	36	49	29	87	99
W1 (Low rate furrow)	0-120	549	410	337	437	188	198
	30-120	328	312	97	70	64	69
	120+	60	52	157	203	26	21
W3 (High rate furrow)	0-120	439	181	206	182	121	83
	30-120	180	100	43	32	28	8
	120+	29	27	43	16	10	7

Table 13. AVERAGE SOIL PARAMETERS AS A FUNCTION OF DEPTH, BLOCK 21 SITE

Depth, cm	Hydraulic conductivity, cm/hr 24 hr	Hydraulic conductivity, cm/hr 24 hr/2 hr	EC_e, mmho/cm	Particle size distribution, % Sand	Silt	Clay
a. Means						
0-30	7.8	1.02	0.67	76	20	4
30-60	5.6	1.05	0.59	74	23	4
60-90	2.6	1.02	0.64	57	37	6
90-120	1.4	1.02	0.66	44	48	7
120-150	1.4	1.06	0.85	44	49	6
b. Standard deviations [a]						
0-30	2.4	.07	.32	4	4	1
30-60	2.4	.07	.18	6	6	1
60-90	2.0	.09	.20	14	12	2
90-120	1.4	.07	.26	14	13	2
120-150	1.2	.08	.58	17	15	3

[a]Expressed as the 58-sample mean, and the respective standard deviation.

profile (80% of the mean vs 72%). Hence, the arguments that sampling variability would be reduced markedly by restricting studies to sprinkler-irrigated fields, or to the lower soil profile (where root-zone variability in solute peaks should be smoothed out somewhat), were not valid at this experimental site.

Variations in Soil Properties at the Block 21 Site

Prior to development of the Block 21 experimental site, personnel from the U.S. Bureau of Reclamation conducted an extensive soil sampling program at the location. Samples were collected on a 31- or 46-meter (100- or 150-foot) grid interval, with a total of 58 soil cores taken from the site area. Data included hydraulic conductivity, settling volume, pH of 1:5 soil:water extracts, electrical conductivity (EC) of saturation extracts, particle-size distribution, and textural classification. A summary of typical data is presented in Table 13. The soils tended to have decreasing sand contents and increasing silt contents with increasing soil depth. Slightly greater amounts of clay also were found with increasing soil depth, but such variations were less marked than for sand or silt values. The replacement of a significant portion of the sand in surface soil samples by silt at greater depths led to substantial reductions in soil hydraulic conductivity. The ratio of 24-hour hydraulic conductivity to 2-hour hydraulic conductivity was nearly unity in all cases, indicating that the samples were quite stable during the passage of water.

Total salt concentrations of the samples, as reflected by EC values, tended to increase slightly with increasing soil depth. However, all soluble salt levels for soils at the site were quite low. Although not provided in the table, pH values increased with depth from an average of 8.4 for surface soils to an average of 9.3 for the greatest soil depths. The pH increase tended to be gradual, rather than being associated with any common zone of major textural change. Settling volumes similarly increased with depth, averaging 15.2 ml for surface soil samples and 16.7 ml for the greatest soil depths. Average percentages of particles in the various sand-size classes were: very coarse sand, 0.2%; coarse sand, 0.7%; medium sand, 2.5%; fine sand, 26.7%; and very fine sand, 46.1%.

Soil characterization data also were grouped and compared for the different experimental areas used each year at the Block 21 site. There was approximately a two-fold variation in 24-hour hydraulic conductivity values of the 0-30 cm depth increments between the areas for the 1969 and 1971 furrow plots and those for the 1969 and 1971 sprinkler plots. Such variations paralleled variations in percent sand, although variations in sand contents were consideraly smaller. The site actually would be ruled fairly uniform with regard to its textural variations at any given soil depth. However, lenses of silty material were interstratified with the sands at many sampling locations, and relatively minor variations in sand and silt contents produced substantial variations in soil hydraulic conductivity. Therefore, variations in the hydraulic properties of the soil could account for much of the lateral sampling variability encountered at this site.

Comparison of Extraction Cup and Soil Sample Values

A disconcerting feature of the extraction cup approach was the large variation in dissolved-N values which existed from one extraction cup to another under supposedly similar experimental conditions. Because of this variation, and in an effort to collect samples from various points on the landscape in order to obtain a better picture of overall trends, the extraction cup program was eventually phased out, with increasing reliance being placed each year on an extensive soil sampling program. A comparison of extraction cup and soil sampling data for comparable treatments and depths at the Block 21 site, and for approximately comparable times, is given in Table 14.

Overall average values for soil solution N were virtually identical for both the extraction cup and soil sampling programs. This provides an important independent check of the reliability of each program, and verifies that the method of extrapolating dissolved-N values from 2:1 water:soil extracts to field water contents on the basis of the ratio in water contents is acceptable. It also indicates that relatively minor changes in soil dissolved-N values occurred during the periods of sampling and transporting samples over the 190 km (120 mile) distance from the Columbia Basin to the laboratory in Pullman. However, despite the good agreement in overall averages, large differences between values for extraction cups and adjacent soil samples were the rule rather than the exception for any given sampling date and depth. Standard deviation values in all cases were nearly as large as the respective averages, because of the wide variations in dissolved-N levels between points only a few meters apart. As indicated above, this is probably due to variations in water movement patterns. An average of a 3.65-fold variation occurred between extraction cup and soil sample values at corresponding times and locations for non-zero levels of nitrogen. When compared to the average concentration level of approximately 105 mg N/liter, and to the recommended drinking water standard of 10 mg N/liter, such variation renders almost meaningless any reliance on detailed data obtained from extraction cups at only a few sites in an irrigated field. Average ratios in extraction cup and soil solution values for the 0- to 120-cm and greater than 120-cm depths were 4.26 and 3.04, respectively, so point-to-point variations in reported concentration for the lower profile were nearly as large as variations for the upper profile.

1972 SEASON

Experiments for the 1972 season were moved to the Othello Research Station of Washington State University, in cooperation with Dr. Robert Kunkel of the Department of Horticulture at WSU. Soils at this location are typical of the older irrigated lands of the Columbia Basin Project, as opposed to the more sandy newer lands typified by the Block 21 experimental site.

Table 14. COMPARISON OF EXTRACTION CUP AND SOIL SAMPLE N VALUES, BLOCK 21 SITE[a] (mg/liter)

Depth, cm	Q1[b] Cup	Q1[b] Soil	Q3 Cup	Q3 Soil	W1 Cup	W1 Soil	W3 Cup	W3 Soil
May 5 (cup) and April 14 (soil)								
90	16	26	17	22	56	34	23	26
180	-	-	-	-	206	97	-	-
240	16	28	102	53	-	-	-	-
basalt	22	12	32	43	-	-	9	8
June 11 (cup) and June 11 (soil)								
60	27	78	-	-	-	-	1330	639
90	71	16	26	14	283	742	77	159
120	-	-	37	8	107	151	-	-
180	40	199	32	15	18	84	-	-
240	16	56	99	63	-	-	-	-
basalt	24	21	43	66	22	37	5	68
July 15 (cup) and July 19 (soil)								
60	262	86	346	1400	15	51	81	28
90	16	43	238	502	385	52	70	42
120	119	25	16	88	132	188	49	59
180	226	166	19	22	150	147	21	51
240	35	64	56	23	-	-	-	-
basalt	38	19	66	34	63	131	69	34
Sept. 9 (cup) and Sept. 24 (soil)								
60	653	348	21	29	84	143	1	41
90	549	258	181	29	9	36	4	30
120	123	165	63	57	3	13	1	13
180	129	55	8	66	19	28	0	12
240	132	88	20	127	-	-	-	-
basalt	31	41	36	14	2	17	1	7

	Averages Cup	Averages Soil	Paired standard deviations
May 5/April 14	50	35	20
June 11	133	136	106
July 15/July 19	112	148	126
Sept. 9/Sept. 24	94	74	52
Overall	103	106	91

[a]1971 season, soil values = means of three replicates from within the crop row. Extraction cup values = means of 1 to 3 samples from replicate plots corresponding to the soil samples.

[b]Q1 = low-rate sprinkler, Q3 = 1.5 x Q1. W1 = low-rate furrow, W3 = 3 x W1.

Furrow-Irrigation Rate Experiment

Summarized average values for dissolved-N in the soil solutions of the furrow-irrigation rate plots at the conclusion of the 1972 growing season are given in Table 15. More detailed data on dissolved-N and dissolved salt levels in samples from this experiment are given in Tables A-10 and A-11 of the Appendix. As is evident from Table 15, concentrations of N in the soil solution varied with location in the field, and with irrigation and fertilization rate. Values at all depths and for all treatments at the tail (outflow) end of the field were several-fold higher than recommended drinking water standards. Lowest dissolved-N levels consistently were found at the head (inflow) end of the field, due to the greater leaching in this area. In general, high dissolved-N values remained in the soil solution whenever an actively-growing potato crop was maintained until the first killing frost of the fall (e.g., in mid-September of 1972).

The data of Tables A-10 and A-11 provide more detailed information on nitrogen and salt distributions as a function of field location, fertilization rate, irrigation rate, sampling depth, and position with respect to existing rows and furrows. Much of the applied N had disappeared from the soil at the head of the field by the end of the season. Although either leaching or nitrogen uptake by plants might explain such data, comparison of the N data with corresponding values for dissolved salts suggests leaching as the main nitrogen loss mechanism. The low N values corresponded almost invariably to low dissolved-salt values and to the higher water application rates (e.g., at the tail of the field). Accumulations at the soil surface may have represented upward flow of soil solution, and evaporation, during the month between frost-kill of the crop and soil sampling. Little difference in N or salt concentrations was observed between row and furrow samples, and variation was nearly as great for

Table 15. DISSOLVED INORGANIC N, FURROW-RATE EXPERIMENT, 1972[a]

(mg/liter)

Location	Depth, cm	High water	Low water	High N	Low N
Head of field	0-60	30	38	47	21
	60+	6	13	10	9
Tail of field	0-60	49	104	88	64
	60+	31	93	88	36

[a]Conclusion of growing season; high water and low water = wetting of alternate sides of a given crop row every 2 and 6 days, respectively; 122 meter irrigation run; high N and low N = 450 and 220 kg N/ha., respectively.

sprinkler-irrigated as for furrow-irrigated plots. Such data support the claim that alternate-furrow irrigation, as commonly practiced in the Columbia Basin, does not lead to the pronounced contrasts between samples from rows versus furrows that are observed commonly for adjacent-furrow irrigation. The data also emphasize the pronounced variations in solute concentrations which can exist from point to point even in "uniformly" treated fields, and support the belief that extensive soil sampling offers the best possibility for obtaining reliable soil solution data in actual growers' fields.

Water flux estimates fell in the range of 0.02 to 0.2 cm/day for this experimental site during the 1972 season. These values are quite low in relation to soil texture and existing irrigation practices, and probably reflect the presence of a compacted layer at the 20- to 30-cm depth in the soil. Such "pans" commonly are observed even during the first year of potato production on these high-silt soils, and limit both root penetration and water flow in many potato fields of the Columbia Basin. The water flux estimates can be combined with values for dissolved nutrient concentrations to provide estimates of the quantities of nutrients being leached under various farm management regimes. For example, a flux of 0.1 cm/day for a 120-day growing season corresponds to 11.9 surface cm of water, or to 59 kg N/ha. at an average dissolved-N level of 50 mg/liter.

Suspension Fertilizer Experiments

Typical trends in dissolved-N values for the soil solution as a function of time are given in Table 16 for replicated samples from the 1972 suspension fertilizer experiment at the Othello Station.

Table 16. DISSOLVED INORGANIC N, SUSPENSION FERTILIZER EXPERIMENT, 1972[a]
(mg/liter)

Treatment	Depth, cm	June 22	Aug. 3	Sept. 1	Nov. 1
670 kg N/ha.	0-60	138	48	54	89
broadcast	60+	190	29	127	43
670 kg N/ha.	0-60	475	245	40	54
banded	60+	118	115	54	42

[a]Othello Station.

Similar trends were observed for both the banded and the broadcast applications, with dissolved-N values decreasing during the growing season, but still several-fold higher than the recommended drinking water standard at the time of the first killing frost. More detailed data from three of the suspension fertilizer plots are presented in the first section of Table A-12 of the Appendix. Standard deviations expressed as a percentage of average concentration values showed similar amounts of variation for each type of placement. Samplings from these experiments provided a partial basis for separation of sampling variability due to fertilizer placement from variability due to variations in soil properties from point to point throughout the experimental area.

Average values for dissolved-N in the soil solution of selected plots from the suspension fertilizer experiment at the end of the 1972 growing season are presented in Table 17. The values increased regularly with increase in fertilizer application rate, and were several-fold higher than the recommended drinking water standard even at the 110 kg N/ha. fertilization rate. The increase in dissolved-N levels at the greater profile depths indicates that some leaching of nutrients beyond the plant root zone occurred even during this single growing season, despite the low water fluxes at the Othello location.

Detailed results of sampling for dissolved-N and dissolved salts in the suspension fertilizer experiment at the end of the 1972 growing season are presented in Tables A-13 to A-15 of the Appendix. The values in Tables A-13 and A-14 permit a comparison of between-plot and within-plot variations in solute concentrations. Although within-plot variations were less than between-plot variations, the latter

Table 17. DISSOLVED INORGANIC N, SUSPENSION FERTILIZER EXPERIMENT, FALL OF 1972[a]
(mg/liter)

Treatment	Depth, cm	110 kg/ha.	450 kg/ha.	670 kg/ha.
Broadcast	0-60	37	49	89
	60+	21	31	43
Banded	0-60	38	45	54
	60+	23	17	42

[a]Othello Station; conclusion of growing season.

variations averaged only 1.8 times the former for the broadcast treatments. Thus, there is a large amount of variation even between values from within the same experimental plot. The method of fertilizer placement does not appear to be a major factor contributing to sample variability by the end of the growing season under conditions similar to those at this experimental site. As evidenced from Table A-15, little difference in either level or variation of dissolved-N values was found between samples from the rows and from the furrows of this experiment. This probably can be attributed to the use of the alternate-furrow irrigation method, with subsequent failure of solutes to accumulate in the crop row as is normal for adjacent-furrow irrigation methods.

Results of continued monitoring throughout the 1972 season of replicates from the 1971 suspension fertilizer experiment are presented in Table 18. As anticipated, dissolved-N levels remained high following the over-winter period, and were related to the fertilizer levels previously applied to the respective plots. Average values in the top 60 cm of the soil profile ranged from 8 to 20 times the recommended drinking water standard, despite the passage of a year since fertilization. A summer fallow period, followed by the planting of a fall ryegrass crop, resulted in much lower dissolved-N levels, with resultant values for the root zone nearly meeting drinking water standards. Most changes probably resulted from N assimilation during the fallow period, as the ryegrass provided only partial surface cover at the time of the fall sampling. No substantial change in subsoil dissolved-N levels was evident by the fall of 1972, although levels for the 670 kg N/ha. N-fertilization rate had decreased by approximately 40 mg/liter. These data suggest the value of a suitable crop rotation following high-level potato production, because of the high dissolved-N concentrations normally remaining in the soil solution following the potato growing season.

Table 18. DISSOLVED INORGANIC N, 1971 SUSPENSION FERTILIZER EXPERIMENT, 1972[a]

Treatment	Depth, cm	Spring of '72		Fall of '72	
		110 kg/ha.	670 kg/ha.	110 kg/ha.	670 kg/ha.
Broadcast	0-60	78	199	12	17
	60+	24	83	31	47
Banded	0-60	81	148	17	31
	60+	39	127	47	87

[a]Othello Station.

Detailed results from the sampling of the 1971 suspension fertilizer experiment are included in Tables A-16 and A-17 of the Appendix. Between-plot variability averaged 1.5 and 1.6 times within-plot variability for the broadcast and banded treatments, respectively, and variability for the banded plots averaged 1.4 times the variability for the broadcast plots. Overall conclusions are similar to those for the 1972 suspension fertilizer experiment.

Summarized yield data from the plots sampled in the 1971 and 1972 suspension fertilizer experiments are presented in Table A-18 of the Appendix. Yields in most cases were substantially higher than those reported for the Block 21 site, and represent yields 50% to 75% higher than the average for commercial fields in the Columbia Basin, though such levels were being approached by a few of the best growers in the area. Substantial increases in total yield and yield of U.S. No. 1 tubers were observed as the rate of fertilizer application was increased from 110 to 450 kg N/ha. However, only minor increases or even decreases in total yield were obtained with further increase in the N-fertilization rate to 670 kg N/ha., and substantial reductions in the yield of U.S. No. 1 tubers were observed at the higher fertilization rates. Part of this latter decrease may be attributed to the early frost, which prevented the crop from filling out many of the tubers formed at the higher rates. Part also may be due to a slowing of early-season growth because of salt effects. In any event, the data suggest that excessively high fertilization rates may have detrimental effects on crop yield as well as on water quality. Hence, careful selection of N-application rates and addition of some supplemental N as crop needs became established during the growing season (instead of attempting to estimate and satisfy all crop needs at the start of the season) should be considered wise management decisions.

Long-term Fertilizer Factorial Experiment

Typical results of the fall 1972 sampling for the long-term fertilizer factorial experiment are presented in Tables 19 and 20. Average values for dissolved-N are presented in Table 19. Levels of 40-60 mg/liter were present in the root zone of all plots, following a uniform application of 480 kg N/ha. in the spring of 1972. The N_1, P_1, and K_1 treatments refer to plots receiving essentially no N, P_2O_5 and K_2O, respectively, since 1965, whereas the N_4, P_4, and K_4 treatments refer to plots receiving approximately 450 kg/ha. of the respective nutrients annually during the same period (except for 1968 and 1969, when wheat was grown to "mine" residual N from the soil). The most noteworthy trend is the high level of dissolved-N which accumulated

Table 19. DISSOLVED INORGANIC N, FERTILIZER FACTORIAL EXPERIMENT, FALL OF 1972[a]
(mg/liter)

Depth, cm	N_1[b]	N_4	P_1	P_4	K_1	K_4
0-60	63	44	44	62	44	63
60+	49	147	102	105	108	99

[a]Othello Station.

[b]N_1 and N_4, P_1 and P_4, and K_1 and K_4 = 0 and 450 kg/ha. of the respective nutrients (as N, P_2O_5, or K_2O) annually for 1965-1967 and 1970-1971. 480 kg N/ha. applied to all plots in 1972.

beneath the N_4 plots. The level is 3 times that beneath the N_1 plots, and nearly 15 times the recommended drinking water standard. Thus, continual growth of potatoes at high N-fertilization levels results in substantial accumulations of N below the root zone, where it constitutes a hazard with respect to ground water contamination. Even the average dissolved-N level below the N_1 plots is several-fold higher than the recommended drinking water standard, and is in the range of minimum dissolved-N levels found during first year cropping to potatoes for other experiments at the Othello Station. This substantiates the assertion that relatively high dissolved-N values are required for high-yield potato production, and that high levels of

Table 20. AVAILABLE P AND K, FERTILIZER FACTORIAL EXPERIMENT, FALL OF 1972[a]
(mg/1000 g soil)

Depth, cm	P_1[b]		P_4		K_1		K_4	
	P	K	P	K	P	K	P	K
0-30	11	194	51	156	33	115	29	235
30-60	4	94	11	84	8	81	7	97
60-120	5	86	7	85	7	84	6	87

[a]Othello Station.

[b]P_1 and P_4, and K_1 and K_4 = 0 and 450 kg/ha. of the respective nutrient (as P_2O_5 or K_2O) annually for 1965-1967 and 1970-1971.

dissolved-N can remain in the soil solution even for N-stressed fields. There was no significant influence of fertilizer phosphorus (P) or of fertilizer potassium (K) on dissolved-N values. As is evident in Table 20, high levels of P fertilization since 1965 have resulted in substantial accumulations of "available" P in the 0-30 cm soil depth, minor accumulations in the 30-60 cm depth, and essentially no changes at greater depths. Levels of available K were lower for the surface layers of the high P plots, which probably reflects the increased plant growth and subsequent nutrient uptake accompanying high soil P levels. Similar trends were observed for available K and P levels as a function of K fertilization rate.

Detailed results from the long-term fertilizer factorial experiment are presented in Tables A-19 to A-21 of the Appendix. As is evident from Table A-19, the greatest increases in residual N beneath the N_4 plots began with the 60 to 90 cm soil depth, and extended through the 180 cm depth. No consistent trends were evident in the data for the top 60 cm of soil profile, which reflects uniform plot fertilization in 1972. Hence, the influence of root activity from a current potato crop appears restricted to the top 60 cm of soil in this area. This results both from the shallow-rooted nature of the potato crop, and from the compacted layer that tends to develop at shallow depths during potato production on these high-silt soils. The data also suggest that N, once it has leached beyond the effective root zone, is neither assimilated nor denitrified to an appreciable extent. This emphasizes the importance of proper water management during potato production to prevent deep percolation whenever possible. It also suggests the merit of including deep-rooted crops in the rotation on a regular basis, to "mine" residual N from the soil profile.

Table A-20 presents average results of soil tests for "available" P and K in the top 30 cm of soil from each plot at selected intervals during the long-term fertility experiments. Some buildup of P levels occurred during the 7 years of analysis even for the low P plots, due to lateral transport by tillage, wind and water. However, the high P fertilization rate increased soil test P values to the upper range of the standard soil test procedure for the area during the first two years of fertilization, with this high level then being maintained throughout the remaining experimental period. Increases in soil K levels were less dramatic, and probably reflect both the high K requirement of the potato crop and the presence of significant amounts of K- "fixing" minerals in soils of the area. An unexplained zone of relatively high soil-test P and K values occurred at the 120 to 180 cm depth for many profiles (Table A-21), but these elements generally were accumulated only in the top 30 cm of soil when applied to the high-fertility plots. Little difference between the high-fertility and low-fertility plots generally was evident for the 60 to 120 cm soil depth and below. The zone high in P and K deep in some of the profiles probably reflects former surface soil buried during the land leveling operations carried out prior to surface irrigation at this site.

In Table A-22, average yield data each year for plots selected for study from the long-term fertility experiment are presented. The problem of delining total yields on lands cropped continually to potatoes is clearly evident from these data, and was only partially rectified by fumigation or by two intervening years of wheat production. Small quantities of residual soil N were being removed by the intervening wheat crop even in its second year of its growth (as evidenced by the 1969 yield data), but the major residual effects were demonstrated in the first year of wheat production. The dramatic increases in potato yields on the N_1 plots in 1971 can be attributed to the application of 110 kg N/ha. to these plots after several years with no N application. Little evidence of residual N effects was detected for the N_4 plots in 1972, when a uniform N application was made to all plots. However, the uniform application was high enough to provide adequate N for most potato production without requiring the utilization of residual soil N.

Slow-Release Nitrogen Experiment

Results of the 1972 slow-release N experiments are summarized in Tables 21, A-12, A-23, and A-24. As is evident in Tables 21 and A-12, partial replacement of the traditional N source with one of the slow-release N sources commonly led to substantial reductions in dissolved-N levels during the growing season. This in turn should lead to less leaching of N whenever excess irrigation water is applied to the crop.

Table 21. DISSOLVED INORGANIC N, SLOW-RELEASE N EXPERIMENT, 1972[a]
(mg/liter)

Treatment[b]	NH_4NO_3		$(NH_4)_2SO_4$	
	Aug. 10	Aug. 29	Aug. 10	Aug. 29
510 kg N/ha.	470	76	106	49
340 kg N/ha. + 170 kg N/ha. as UF	136	24	74	14
340 kg N/ha. + 170 kg N/ha. as SC 20	404	59	40	36
340 kg N/ha. + 170 kg N/ha. as SC 30	139	33	160	36

[a]Othello Station.
[b]Rate listed first = traditional source (NH_4NO_3 or $(NH_4)_2SO_4$); rate listed second = slow-release N source (urea formaldehyde, or sulfur-coated urea releasing 20% or 30% of its N in 7 days under standardized conditions).

Substantial leaching of N appeared to have occurred by August 10 for some of the sulfur-coated urea plots. However, such leaching may have been due to the traditional N sources which comprized the bulk of the applied N, rather than to the slow-release N formulations. By August 29, use of the slow-release N sources had led to substantially lower soil solution N values in virtually all cases. With the exception of one urea-formaldehyde treatment, little change in dissolved-N values below the first 30 cm of the soil profile was evident from the slow-release N sources (Table A-23). However, high N concentrations were evident in the surface soil at the end of the season for all N sources. This probably reflects N release and/or accumulation from the deeper soil depths between the time of the killing frost in mid-September and the sampling in late October. Plant uptake of released N would no longer occur during this period.

Average yield data for the plots sampled from the slow-release N experiment are presented in Table A-24. Total yields were similar for both the 340 and 500 kg N/ha. rates of each standard N source, but yields of U.S. No. 1 tubers were consistently lower at the 500 kg/ha. rate. Those treatments employing slow-release nitrogen sources generally averaged both higher total yields and higher yields of U.S. No. 1 tubers than did the corresponding 500 kg/ha. standard treatments, although they averaged lower yields of U.S. No. 1 tubers than did the 340 kg/ha. standard treatments. Thus, use of slow-release N sources eventually may become competitive with conventional fertilizer treatments wherever environmental concerns are a significant factor in the selection of a crop fertilization program.

Plant Population Experiment

Still another experiment at the Othello station in 1972 involved the sampling of residual N from a 1971 experiment in which both the plant population per acre and the N fertilization rate were varied, in order to assess the feasibility of tailoring fertilization programs to the actual number of plants growing in a given field. This addresses a significant problem in potato production, because of the difficulty in predicting plant populations prior to crop emergence. Results of soil sampling in the spring of 1972 are given in Table A-25, and yield data for the corresponding plots are provided in Table A-26. Little difference in residual N was evident for the various treatments following the over-winter period. Differences in residual N had persisted for a similar sampling program on the 1971 suspension fertilizer experiment (Table A-16), and hence major differences in residual N from the various treatments probably never really materialized. As would be expected, higher total yields were obtained from high plant populations per acre than from low plant populations. Differences were greater for 1971 than for 1972, which may result from the early killing frost in 1972. Yields of U.S. No. 1 tubers also were increased substantially by increasing plant population at the low N-fertilization rate, but not at the high N-rate. This substantiates results discussed previously, where higher N-fertilization rates often resulted in reduced yields of U.S. No. 1 tubers, despite increases in total yield with increased fertilization rate.

Variations in Soil Properties on the Othello Station

Sampling for soil variability at the Othello Field Station was less extensive than conducted by the Bureau of Reclamation for the Block 21 site. However, mechanical analyses were performed for a large number of samples from this site, with the results summarized in Table 22. The main textural variation at the site was in sample silt content, with a corresponding opposite variation in sample sand content. The majority of the sand was in the very fine sand fraction, so distinctions between sand and silt contents often were rather arbitrary.

Table 22. VARIATIONS IN SOIL SILT CONTENT, EXPERIMENTAL PLOTS, OTHELLO STATION[a]
(%)

	Depth, cm				
Experiment	0-30	30-60	60-120	120-180	180-240
Overall	54±5	58±5	59±6	59±11	56±13
Fertilizer Factorial	53±3	59±2	56±10	46±7	38±5
Suspension Fertilizer	51±1	55±1	63±2	55±1	---
Irrigation Rate	55±6	60±4	59±5	63±11	68±8
Sprinkler Plots	51±2	55±1	62±2	59±5	55±3
Paired Row-Furrow Sets	54±1	58±2	59±2	60±2	58±4

[a]1972 experiments; clay contents = 2-4% (average = 2.5±0.6%); average sand fractions: very coarse sand = 0.5±1.0%, coarse sand = 1.4±1.6%, medium sand = 1.5±0.9%, find sand = 15.2±6.2%, and very fine sand = 81.5±7.1%.

Trends were less consistent at this site than for the Block 21 site, and overall average variations in texture with depth were small. Sets of samples from rows and adjacent furrows exhibited only small differences, so variations generally were on a rather large lateral scale. Soil test values for "available" P and K (not given) suggested considerably more variation in field soil properties than did mechanical analysis data. Such differences probably reflect both differences in location of the original surface soil with respect to the present soil surface and variations in fertility applications during the subsequent ten years of farm operation.

In summary, variations in soil texture were relatively slight throughout both the Block 21 and Othello Station experimental areas. From this standpoint, the areas represented good units for experimental measurements. However, variations in hydraulic conductivity and soil fertility were more pronounced, and probably relate more meaningfully to the variations in soluble salt and dissolved-N levels which were observed. Both fields had been leveled previously to permit surface irrigation operations, as is typical for many of the older lands of the Columbia Basin Project. Many of the more recently-developed lands in the Basin area have been left unleveled and irrigated with sprinkler-irrigation systems. Variations in surface hydraulic conductivity and surface fertility levels should be less pronounced at such sites than at the two sites characterized for this report.

Comparison of Extraction Cup and Soil Sampling Values

A comparison of extraction cup and soil sampling values for dissolved-N in soil solutions at the Block 21 site was given previously. Similar data are summarized in Table 23 for the 1972 and 1973 growing seasons at the Othello station. As for the Block 21 site, overall values of average extraction cup and soil sampling estimates agreed quite closely, but values for individual depths and sampling times (as reflected by the standard deviations) varied widely. Once again, the data dramatize the difficulty of using values from a few extraction cup sites to predict behavior on a field-wide basis.

1973 SEASON

Although some experiments for the 1973 season were maintained on the Othello research station, the main portion of the season's program involved extensive sampling of the soil solution in actual growers' fields. Dr. Robert Kunkel had negotiated with several growers to install several standardized experiments in their fields,

Table 23. SUMMARIZED COMPARISON OF EXTRACTION CUP AND SOIL SAMPLE N VALUES, OTHELLO STATION[a] (mg/liter)

Date	Average (cup)	Average (soil)	Standard deviation
1972 season[b]			
7-21 or 7-28	71	74	51
8-18 or 8-25	54	50	38
9-8 or 9-15	42	48	30
Overall	56	57	40
1973 season[c]			
5-29 or 6-11	404	283	335
7-6	242	336	400
8-28 or 8-29	98	94	106
Overall	225	209	274

[a]Soil and extraction cup samples from within the crop row, at the depths and dates specified, within a few meters of one another.

[b]Averages for 10 furrow-irrigated sites (averaging 3.6 depths each) and 5 sprinkler-irrigated sites (averaging 2.6 depths each).

[c]Averages for 14 sprinkler-irrigated sites (averaging 3.1 depths each).

in order to obtain an appraisal of yield changes to be expected from several management variables under commercial conditions. The main experiments monitored as part of our program during this season were the suspension fertilizer experiment and the slow release N experiment. Each of these experiments was discussed previously in the section describing the 1972 growing season.

Suspension Fertilizer Experiments

Tri-cities area -

One set of suspension fertilizer experiments was placed in a field irrigated by a center-pivot irrigation system and located approximately 65 km east and north of the Tri-cities (Richland, Pasco, and

Kennewick) area. The soil at this site was a silt loam, and proved to be so fine-textured that considerable runoff and surface ponding of water invalidated many of the yield data. As a result, it was decided mid-way through the season not to harvest the plots at this location. However, soil samples were obtained from the field on June 12 and August 20, and summarized results are presented in Table 24. High levels of dissolved inorganic N in the surface 0-60 cm of soil were observed in all cases for the early sampling date. Values in the root zone on this date averaged 2.3-fold higher for the high fertilization rate than for the low rate. However, no differential leaching of N below the 60 cm depth for the more heavily fertilized plots was apparent at this time. Subsoil N concentrations in all cases were in the range of 35-70 mg N/liter, reaffirming that concentrations of this magnitude commonly are left in the soil from preceeding potato crops. Standard deviations as a percentage of the respective means were essentially identical for both subsoil and root zone samples.

By August 20, increases in dissolved inorganic N were apparent for subsoil samples from all of the more heavily-fertilized treatments. Average values for dissolved inorganic N in the root zone also remained generally higher for the higher fertilization rate, except where sampling variability obscured the trend. Dissolved-N levels below the plant root zone averaged 39 mg/liter for the low fertilization rate and 68 mg/liter for the high fertilization rate, or 4 and 7 times the recommended drinking water standard, respectively. Standard deviations for dissolved-N in the root zone and beneath the root zone averaged 100% and 83% of the respective means, so lateral variations in dissolved-N levels were maintained to considerable depths at this site.

Average dissolved-N levels in the plant root zone were lower for the fumigated plots. This may reflect either higher yields or inhibition of the nitrification process, with subsequent maintenance of larger amounts of ammonium N, in the fumigated soils.

Horse Heaven Hills area -

Cooperative experiments during 1973 in the Horse Heaven Hills area also included a field irrigated by center-pivot irrigation on a considerably more sandy site. Ponding during the irrigation season was not a problem at this location. Dissolved-N in the root zone of the field on May 23 was higher in six of eight cases for the higher fertilization rate, with values averaging 177 and 204 mg/l, respectively, for the two rates (Table 25). No consistent change in root zone dissolved-N levels was evident for the fumigated samples.

Table 24. DISSOLVED INORGANIC N, SUSPENSION FERTILIZER EXPERIMENTS, TRI-CITIES AREA, 1973[a]

Treatment[b]	June 12				August 20			
	Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %	
	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm
Fumigated								
F1BaL	163	58	23	46	239	38	86	47
F4BaL	352	54	90	70	113	51	102	128
F1BaD	216	69	60	69	185	51	80	37
F4BaD	782	56	86	42	311	64	96	64
F1BrL	205	53	37	103	39	34	119	100
F4BrL	358	43	94	72	224	100	118	148
F1BrD	108	47	53	74	20	31	106	81
F4BrD	92	55	78	59	63	55	95	62
Chiseled Only								
F1BaL	289	47	120	87	-	-	-	-
F4BaL	418	54	67	84	-	-	-	-
F1BaD	230	54	56	51	-	-	-	-
F4BaD	984	51	74	69	-	-	-	-
F1BrL	190	38	71	82	-	-	-	-
F4BrL	413	35	125	60	-	-	-	-
F1BrD	144	51	53	41	-	-	-	-
F4BrD	287	39	46	63	-	-	-	-

[a]Center-pivot irrigation, silt loam site.

[b]F1 and F4 = 110 and 450 kg/ha. N, P_2O_5, and K_2O, respectively. Ba = banded, Br = broadcast, L = suspension fertilizer, D = dry fertilizer. Fumigation with Telone C at a rate of 230 liter/ha. (25 g/a). Planted May 7-8, plots not harvested, due to ponded conditions in much of the experimental area.

Table 25. DISSOLVED INORGANIC N AND YIELD DATA, SUSPENSION FERTILIZER EXPERIMENTS, HORSE HEAVEN HILLS AREA, 1973[a]

Treatment[b]	May 23				June 27				Yield[c]	
	Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %		Total, quintal/ha.	U.S. No. 1's, %
	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm		
Fumigated										
FlBaL	83	60	46	71	—	—	-	-	452	95
F4BaL	141	46	86	69	—	—	-	-	525	93
FlBaD	74	35	86	93	—	—	-	-	458	94
F4BaD	152	65	83	96	—	—	-	-	506	94
FlBrL	239	39	111	50	30	49	50	66	516	93
F4BrL	268	53	64	27	121	112	117	22	493	93
FlBrD	319	66	86	33	66	73	80	77	504	94
F4BrD	250	48	68	20	187	141	104	60	495	95
Chiseled Only										
FlBaL	41	60	61	44	—	—	-	-	463	87
F4BaL	115	36	82	74	—	—	-	-	409	91
FlBaD	56	62	75	49	—	—	-	-	390	87
F4BaD	188	61	69	42	—	—	-	-	357	88
FlBrL	159	56	113	103	—	—	-	-	427	84
F4BrL	190	127	84	26	—	—	-	-	463	86
FlBrD	446	73	97	57	—	—	-	-	400	89
F4BrD	331	106	78	110	—	—	-	-	383	82

[a]Center-pivot irrigation, sandy site.

[b]All plots received 50 kg P_2O_5 /ha. and 200 kg K_2O/ha. (both preplant broadcast) and 250 kg N/ha. (50 kg/ha. preplant broadcast, 200 kg/ha. sprinkler-applied) from the grower in addition to the experimental treatments. Fl and F4 = 0 and 270 kg/ha. N, P_2O_5, and K_2O, respectively. Ba = banded, Br = broadcast. L = suspension fertilizer, D = dry fertilizer. Fumigation with Telone C at 230 liters/ha. (25 gal/a.). Planted March 16-19, harvested August 1. Kennebec potatoes.

[c]Quintal/ha. = cwt/acre x 1.12.

Greater leaching of N occurred at this sandy site, as was already evident by May 23. Average values for dissolved-N below the plant root zone for the two fertilization rates on this date were 56 and 68 mg/l, respectively. The trend was even more evident by June 27, when average values for dissolved-N below the root zone for the two fertilization rates were 61 and 127 mg/l, respectively. Higher root zone dissolved-N levels also persisted for the higher rate on the latter date, with average values for the two fertilization rates of 48 and 154 mg/l, respectively.

Values for standard deviation as a percentage of the mean were lower for the subsoil than for the root zone, with respective values for the two zones on May 23 of 81% and 60%, and on June 27 of 88% and 56%.

Overall response to increased N fertilization at this site was negligible, with average yields of 451 and 455 quintals/ha. for the two fertilization rates. Potato quality was also independent of fertilization rate, with an average of 91 percent U.S. No. 1 tubers produced at each rate. A slightly greater amount of N appeared to be required for the higher yields obtained from the fumigated plots. Average values for percent U.S. No. 1 tubers were 94% for the fumigated treatment and 87% for the chiseled-only treatment.

It appears that the 245 kg N/ha. applied to the F1 fertilization plots was adequate for optimum potato growth at this site. A question which cannot be answered from these data alone is the question of how much this relatively-low N fertilization rate would need to be increased if the site were in its first year of potato production, rather than being a site recropped to potatoes.

Moses Lake area -

Results of the 1973 suspension fertilizer experiment in the Moses Lake area are provided in Tables 26 and A-27. Surface soil dissolved-N values are subdivided by sampling location with respect to the plant row in the latter table.

Values for dissolved-N in the root zone generally were higher for the higher fertilization rate, and tended to decrease considerably during the growing season for both rates. An apparent leveling off of dissolved-N levels between August and October may have resulted from some upward movement of water, and subsequent evaporation at the soil surface, following the irrigation season.

Table 26. DISSOLVED INORGANIC N AND YIELD DATA, SUSPENSION FERTILIZER EXPERIMENTS, MOSES LAKE AREA, 1973[a]

Treatment[b]	Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %		Yield[c]	
	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	Total, quintal/ha.	U.S. No. 1's, %
June 7 and 11					October 2					
F1BaL	217	12	60	114	67	9	114	108	513	70
F4BaL	453	29	86	102	236	19	99	97	608	53
F1BaD	312	24	79	88	67	16	56	68	586	61
F4BaD	660	17	100	69	124	28	58	124	628	56
F1BrL	66	17	92	43	38	7	75	152	385	60
F4BrL	206	51	124	135	109	7	102	148	483	59
F1BrD	39	12	93	113	25	11	120	100	380	43
F4BrD	209	45	68	32	22	6	100	210	438	52
August 14										
F1BaL	44	2	84	200						
F4BaL	221	25	115	136						
F1BaD	104	1	115	100						
F4BaD	94	0	136	-						
F1BrL	57	10	78	80						
F4BrL	110	2	82	150						
F1BrD	20	0	166	-						
F4BrD	35	4	167	175						

[a] Rill irrigation, sandy site.
[b] F1 and F4 = 110 and 450 kg/ha. N, P_2O_5, and K_2O, respectively. Ba = banded, Br = broadcast. L = suspension fertilizer. D = dry fertilizer. Planted May 1-2, harvested October 4-5. Russet Burbank potatoes.
[c] Quintal/ha. = cwt/acre x 1.12.

Values for dissolved-N levels below the plant root zone at this location also tended to reflect differences in fertilization rate, although such concentrations were considerably lower for this furrow-irrigated site than for any of the sprinkler-irrigated sites. This partially reflects greater leaching of the furrow-irrigated plots. However, root zone dissolved-N levels remained relatively high throughout the growing season at the Moses Lake site, suggesting that considerable "entrapment" of nitrogen in the ridge area resulted from the alternate-furrow irrigation practice carried out at this location. Much of the root zone N is moved back and forth in the ridge during the irrigation season, but dissolved-N deeper in the soil profile is leached out of the profile by the excess water applied when furrow irrigation is practiced on such sandy sites. Subsoil dissolved-N levels at both fertilization rates were of the same order of magnitude as the maximum drinking water standard throughout most of the growing season at this site, so dilution by the leaching waters considerably lessened the ground water contamination hazard.

Standard deviations as a percentage of the means were as high or higher in the area below the root zone as within the root zone at this site. However, this is misleading because of the low values for dissolved-N in the lower soil profile. Average percentage standard deviation values varied from 88% to 118% of the respective means.

A significant response to N was obtained at this location, which reflects the leaching (and particularly early-season leaching) which occurred. Total yields for the two fertilization rates were 466 and 540 quintal/ha., respectively. A combination of periodic N-stress and water stress resulted in relatively poor tuber quality, with average figures for percentage of U.S. No. 1 tubers for the two fertilization rates being 59% and 55%, respectively.

Data for the sampling of surface soils at this site as a function of position with respect to the plant row are included in Table A-27. On August 1, average levels for dissolved-N in the surface 30 cm of soil for the row, the furrow, and halfway between the two were 102, 11, and 23 mg/l, respectively. Thus, the highest concentration of dissolved-N was beneath the fertilizer row, as would be expected from normal water movement patterns in furrow-irrigated soils. On August 14, the concentrations of dissolved-N beneath the furrow were actually higher than beneath the row, because a recent irrigation had moved much of the N laterally to this location.

Standard deviations as a function of time and of position with respect to the potato row were high in all cases. They averaged 90% and 68% of the respective means for the sampling position study on August 1 and August 14, compared to corresponding standard deviations for the entire replicates on these dates of 115% and 107%, respectively. The higher overall values reflect the variations which occurred in dissolved-N with sampling location, but the exact locations of high N and low N zones could not be predicted without a prior knowledge of recent wetting patterns under the alternate-furrow irrigation regime.

Othello area -

A final set of 1973 suspension fertilizer experiments was conducted on a silt loam site in the Othello area, where irrigation was carried out using a solid-set sprinkler system. Appropriate data for the soil sampling program at this location are included in Tables 27 and A-28.

Average levels of dissolved-N in the plant root zone reflected fertilization rates, with high-rate values averaging 2 to 5 times the low-rate values throughout the growing season. Values had decreased to only 2 to 6 times the recommended drinking water standard by late August. A subsequent increase in concentration by October 16 probably reflected upward movement of solutes and surface evaporation of water following the irrigation season.

Values for dissolved-N in subsoil samples at this site also reflected differences in fertilization rate. Values were considerably higher than those observed for the other grower's fields, reflecting a higher initial level of fertility due to prior management practices. Substantial downward movement during the current irrigation season was also evident. The higher soil N levels were also reflected by the yield data (Table 27), with average total yields for the two fertilization rates of 730 and 743 quintal/ha., respectively. Average percentages of U.S. No. 1 tubers were 59% and 52%, so weight of U.S. No. 1 tubers actually declined by nearly 12% at the higher fertilization rate.

Average standard deviation values, expressed as a percentage of the mean, were approximately 100% for both the root zone (0-60 cm) and subsoil (greater than 60 cm) zones. These values are of the same magnitude as those obtained at the furrow-irrigated site near Moses Lake, so mere sampling of sprinkler-irrigated fields, as opposed to furrow-irrigated fields, does not eliminate most of the inherent soil solution sampling variability.

Results of dissolved-N sampling in relation to location near the plant row are given in Table A-28. For the lower fertilization rate, N concentrations decreased gradually during the growing season and were close to the drinking water maximum during most of August. However, minimum values averaged 3 to 4 times the drinking water

Table 27. DISSOLVED INORGANIC N AND YIELD DATA, SUSPENSION FERTILIZER EXPERIMENTS, OTHELLO AREA, 1973[a]

Treatment[b]	Dissolved N, mg/l 0-60 cm	60+ cm	Std. deviation, % 0-60 cm	60+ cm	Dissolved N, mg/l 0-60 cm	60+ cm	Std. deviation, % 0-60 cm	60+ cm	Yield[c] Total, quintal/ha.	U.S. No. 1's, %
May 29					August 22					
F1BaL	689	44	101	75	6	28	113	86	716	68
F4BaL	1045	75	88	87	93	145	147	91	740	59
F1BaD	154	37	72	49	22	144	124	166	754	60
F4BaD	575	99	110	54	66	114	94	122	808	55
F1BrL	139	119	65	163	56	155	141	117	713	60
F4BrL	240	79	104	66	66	182	130	125	584	51
F1BrD	90	60	40	93	8	5	125	100	739	49
F4BrD	184	92	79	72	7	1	95	200	840	41
July 17					October 16					
F1BaL	4	127	57	80	71	70	48	92		
F4BaL	290	111	137	86	295	133	83	119		
F1BaD	8	79	142	75	74	37	62	104		
F4BaD	141	358	124	18	77	139	59	138		
F1BrL	148	211	168	162	73	77	102	116		
F4BrL	413	113	146	35	153	100	97	70		
F1BrD	5	80	142	156	35	37	52	109		
F4BrD	46	44	104	59	47	72	52	129		

[a]Solid-set sprinkler, irrigation, silt loam site.

[b]F1 and F4 = 110 and 450 kg/ha. N, P_2O_5 and K_2O respectively. Ba = banded, Br = broadcast. L = suspension fertilizer, D = dry fertilizer. Fumigation with Telone C at 230 liters/ha. (25 gal/acre). Planted April 20-24, harvested October 17-19. Russet Burbank potatoes.

[c]Quintal/ha. = cwt/acre x 1.12.

standard at the higher fertilization rate. No consistent trend with relation to sampling position was evident on any of the sampling dates. Values tended to be somewhat higher beneath the crop row, perhaps because of greater upward movement and evaporation at this location between irrigations, but differences were relatively minor after the first sampling date. Values for standard deviation as a percentage of the mean also appeared unrelated to sample location. However, the standard deviation values were substantially lower than values for the furrow-irrigated site near Moses Lake, indicating considerably more uniformity with respect to sampling position (because of the lack of lateral flushing of salts and accumulation in the zone of most recent wetting front advance) for the sprinkler-irrigated field.

Slow-Release Nitrogen Experiments

A series of experiments in which several slow-release N sources were compared to traditional N sources was also placed in grower's fields during the 1973 season. Results of the experiments are summarized below.

Tri-Cities area -

Results of the slow-release N experiment for the silt loam site in the Tri-Cities area are given in Table 28. This was the site at which serious ponding resulted from inadequate water filtration when center-pivot irrigation was employed for a fine-textured soil, so no yield data were obtained for the experiments. Increasing N application rates resulted in higher root zone dissolved-N values, with correspondingly greater potential for N leaching during the growing season. Use of slow-release N fertilizers substantially decreased average dissolved-N values in most cases. The more readily-soluble slow-release N source (SCU 100) tended to produce higher dissolved-N levels early in the season than did the more insoluble, slow-release N sources (e.g., SCU 25). The effect was less pronounced later in the season, which may reflect a longer preservation of soluble N in the root zone for forms releasing their N more slowly.

Values for dissolved-N in soil solutions below the root zone were not related to N fertilization rate or to fertilizer form early in the season. Slightly higher values for some of the slow-release N plots on August 20 may or may not reflect effects from the formulations themselves, for initial soil N levels were higher in this case for the slow-release N plots as well. Values for subsoil dissolved-N ranged from 2 to 11 times the maximum drinking water standard, necessitating good water management if deep percolation and contamination of local ground water supplies were to be avoided in this case.

Table 28. DISSOLVED INORGANIC N, SLOW-RELEASE N EXPERIMENTS, TRI-CITIES AREA, 1973[a]

Treatment[b]	June 12 Dissolved N, mg/l 0-60 cm	June 12 Dissolved N, mg/l 60+ cm	June 12 Std. deviation, % 0-60 cm	June 12 Std. deviation, % 60+ cm	August 20 Dissolved N, mg/l 0-60 cm	August 20 Dissolved N, mg/l 60+ cm	August 20 Std. deviation, % 0-60 cm	August 20 Std. deviation, % 60+ cm
170 kg/ha. NH_4NO_3	521	82	41	73	120	7	160	114
170 kg/ha. $(NH_4)SO_4$	347	67	46	74	-	-	-	-
170 kg/ha. Urea	233	40	45	37	71	27	91	100
170 kg/ha. SCU 100	345	41	25	79	37	11	115	82
170 kg/ha. SCU 45	147	166	38	85	-	-	-	-
170 kg/ha. SCU 25	106	128	35	96	48	32	128	106
390 kg/ha. NH_4NO_3	592	42	34	38	329	31	116	61
390 kg/ha. $(NH_4)_2SO_4$	320	44	90	52	-	-	-	-
390 kg/ha. Urea	431	51	30	55	446	25	123	48
390 kg/ha. SCU 100	403	90	91	91	195	57	68	58
390 kg/ha. SCU 45	506	46	109	39	-	-	-	-
390 kg/ha. SCU 25	312	74	55	72	181	63	92	70

[a]Center-pivot irrigation, silt loam site.

[b]SCU 100, 45 and 25 = sulfur-coated ureas releasing 100%, 45%, and 25% of their N, respectively, during the standard 7-day leaching test. Planted May 7-8, plots not harvested, due to ponded conditions in much of the experimental area.

Values for average standard deviations as a percentage of the means were actually greater for the deeper soil depths on June 12, though this trend was reversed by August 20. Once again, the early-season values more probably reflected prior N accumulations. No consistent difference with fertilizer source was evident.

Horse Heaven Hills area-

Similar data for the 1973 slow-release N experiments in the Horse Heaven Hills area are given in Table 29. Traditional N sources tended to produce higher root zone dissolved-N levels early in the season than did slow-release N sources, but the trend was reversed by mid-season. The slow-release N sources produced lower subsoil dissolved-N levels on both sampling dates. This suggests that slow-release N provides a feasible means for controlling N losses on sandy sites, particularly during early-season growth. However, the higher resultant soil dissolved-N levels in mid- to late-season produce an off-setting tendency for leaching of N by that time, if water management is not carefully regulated.

Values for average standard deviations as a percentage of the respective means were higher on both sampling dates for root zone samples than for those from the subsoil. No consistent differences in these values for the slow-release N and traditional N sources were evident on the two sampling dates.

Total yields were higher for slow-release N sources at this site than for traditional N sources, with average values of 412 and 385 quintal/ha., respectively. Total yields also increased steadily with decreasing solubility of the slow-release sources (in other words, in going from highly soluble SCU 70 to fairly insoluble SCU 30). This suggests that rate of N release is an important factor in preventing leaching and insuring N availability throughout the growing season at sandy sites. However, tuber quality decreased with decreasing solubility of the slow release N sources as well, so the rate of N release in this case may have been marginal for high quality tuber production. Average values of greater than 90% U.S. No. 1 tubers were obtained for the suspension fertilizer experiments at the same site. A slight increase in yield also was observed at this site in going from 220 to 280 kg/ha. of traditional N, with respective average yields of 379 and 391 quintal/ha. No difference was observed in percentage of U.S. No. 1 tubers between the two rates of traditional N. Because of the slightly higher percentage of U.S. No. 1 tubers produced by traditional sources, there was virtually no difference in total yield of U.S. No. 1 tubers between the various N sources.

Table 29. DISSOLVED INORGANIC N AND YIELD DATA, SLOW-RELEASE N EXPERIMENTS, HORSE HEAVEN HILLS AREA, 1973[a]

	May 23-24				June 29				Yield[c]	
	Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %		Total,	U.S. No.
Treatment[b]	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	quintal/ha.	1's, %
220 kg/ha. SCU 70	477	47	99	90	153	46	145	57	388	83
220 kg/ha. SCU 47	253	42	97	42	189	51	80	46	396	77
220 kg/ha. SCU 30	327	64	90	57	337	94	198	97	452	77
220 kg/ha. NH_4NO_3	361	129	66	141	-	-	-	-	388	83
280 kg/ha. NH_4NO_3	-	-	-	-	223	101	130	58	360	79
220 kg/ha. $(NH_4)_2SO_4$	491	60	77	59	-	-	-	-	388	82
280 kg/ha. $(NH_4)_2SO_4$	-	-	-	-	133	93	84	26	422	82
280 kg/ha. Urea	555	61	55	75	-	-	-	-	362	85
280 kg/ha. Urea	-	-	-	-	95	120	155	105	390	85

[a] Center-pivot irrigation, sandy site.
[b] SCU 70, 47, and 30 = sulfur-coated ureas releasing 70%, 47%, and 30% of their N, respectively, during the standard 7-day leaching test. Planted March 15, harvested August 6. Kennebec potatoes.
[c] Quintal/ha. = cwt/acre x 1.12.

Moses Lake area -

Summarized results for the 1973 slow-release N experiments in the Moses Lake area are given in Tables 30 and A-27. Average values for dissolved inorganic N in the root zone were consistently higher for the higher fertilizer rate at this site. Mid-season values for dissolved-N in the root zone at a given fertilization rate were decreased substantially for the slow-release N sources compared to the traditional N sources. However, by October 2, nearly identical or even higher average concentrations of dissolved-N remained in the root zone soils of the slow-release N plots. The data substantiate a tendency for relatively high levels of N to remain in the root zone at season's end when slow-release N sources are employed, although values for dissolved-N during the growing season are substantially lower when using such sources.

As with the suspension fertilizer experiments, relatively low values for subsoil dissolved-N were observed at this site. Values were slightly higher for the higher fertilization rates when using traditional N sources, but none of the differences were large. Average values ranged from about 1/2 to 2 times the maximum recommended drinking water standard. As for the suspension fertilizer experiment, the low values apparently resulted from the movement of much of the soil N laterally when the alternate-furrow irrigation technique was employed, with a concurrent rather rapid flushing of any N from the soil below the plant root zone during furrow irrigation at this sandy site.

Higher yields actually were obtained for traditional N sources than for slow-release N sources at this particular site, with yields for the two sources averaging 409 vs. 389 quintal/ha. at the 170 kg/ha. fertilization rate and 559 vs. 479 quintal/ha. at the 390 kg/ha. rate. Average percentages of U.S. No. 1 tubers were in the range 50-55% for all fertilizer sources and rates. Thus, there was a significant response to N at the site, which probably reflects the accentuated tendency for N leaching whenever furrow irrigation is practiced on a sandy soil. The slow-release N sources did not produce the anticipated increase in yield under furrow-irrigated conditions, but this may be because the rate of N release was inadequate to meet the N demands of the crop in this situation.

A comparison of dissolved-N values in the surface 30-cm of soil for various sampling locations with respect to the crop row are presented in Table A-29. Higher values were observed in all cases for the higher fertilization rates. Highest dissolved-N values were obtained for the crop row on August 1, but the trend was actually reversed on August 14, because of average wetting front movement to the position

Table 30. DISSOLVED INORGANIC N AND YIELD DATA, SLOW-RELEASE N EXPERIMENTS, MOSES LAKE AREA, 1973[a]

Treatment[b]	Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %		Yield[c]	
	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	Total, quintal/ha.	U.S. No. 1's, %
	June 7				October 2					
170 kg/ha. NH_4NO_3	74	3	79	133	51	15	81	86	436	53
170 kg/ha. Urea	217	12	58	83	65	7	134	188	382	54
170 kg/ha. SCU 100	144	8	45	56	48	9	40	94	364	51
170 kg/ha. SCU 45	75	12	86	78	87	12	83	105	476	53
170 kg/ha. SCU 25	89	15	75	60	29	0	90	-	325	42
390 kg/ha. NH_4NO_3	706	32	60	41	146	26	80	17	530	54
390 kg/ha. Urea	334	32	55	109	108	24	44	31	588	56
390 kg/ha. SCU 100	190	7	71	107	121	21	38	65	526	60
390 kg/ha. SCU 45	368	7	29	55	274	24	113	178	440	57
390 kg/ha. SCU 25	60	11	105	55	95	22	78	107	473	51
	August 14									
170 kg/ha. NH_4NO_3	147	3	138	100						
170 kg/ha. Urea	38	2	96	200						
170 kg/ha. SCU 100	68	12	86	83						
170 kg/ha. SCU 45	-	-	-	-						
170 kg/ha. SCU 25	23	0	167	-						
390 kg/ha. NH_4NO_3	93	12	171	167						
390 kg/ha. Urea	127	4	83	100						
390 kg/ha. SCU 100	79	4	57	100						
390 kg/ha. SCU 45	-	-	-	-						
390 kg/ha. SCU 25	23	1	128	100						

[a]Rill irrigation, sandy site.

[b]SCU 100, 45 and 25 = sulfur-coated ureas releasing 100%, 45%, and 25% of their N, respectively, during the standard 7-day leaching test. Planted May 1, harvested October 8. Russet Burbank potatoes.

[c]Quintal/ha. = cwt/acre x 1.12.

of the adjacent furrow during the most recent alternate-furrow irrigation at the site. Average dissolved-N levels were higher in all cases for traditional N sources than for slow-release N sources.

No consistent variation in standard deviations as a percentage of the respective means was evident as a function of either fertilizer source or fertilization rate. Respective values by sampling position averaged 65% on both August 1 and August 14, with overall values for the replications approximating 100% for each date. As indicated previously, this reflects the tendency of the dissolved-N to be concentrated in the zone of most recent wetting-front advance whenever sampling is conducted.

Othello area -

Results of experiments on the use of slow-release N at the silt loam site in the Othello area are presented in Tables 31 and A-30. Values for dissolved inorganic-N in the root zone generally increased with increasing fertilization rate, except for situations where high sampling variability was encountered near the localized fertilizer band early in the growing season. The slow-release N sources produced lower dissolved-N values during early- and mid-season sampling, but produced higher dissolved-N values in the plant root zone late in the year. This indicates a decrease in potential for N leaching early in the season, but substantial N carryover to subsequent seasons at high fertilization rates. Thus, it is important that the slow-release N application be tailored as closely as possible to actual crop needs, so that significant N leaching does not occur during over-winter periods. Values for dissolved-N in the root zone for this experiment dropped to acceptable drinking water standards by late season, even though they increased again by the end of the season because of upward movement of solution and/or because of continued release of N after plant uptake of the element had essentially ceased.

Values for dissolved-N below the plant root zone generally reflected increases in fertilization rate and in the proportion of traditional (vs. slow-release) N sources. The relatively large amounts of water passing through the plant root zone at this location are reflected by the relatively rapid movement of dissolved-N out of the soil beneath the root zone by late summer at the low fertilization rate, and by the rapid accumulation of N in the soil beneath the root zone at the high fertilization rate (particularly when using traditional N fertilizer sources). Values for dissolved-N beneath the plant root zone averaged less than three times the drinking water standard for the low fertilization rate (25 mg/l), but averaged nearly 11 times the drinking

Table 31. DISSOLVED INORGANIC N AND YIELD DATA, SLOW-RELEASE N EXPERIMENTS, OTHELLO AREA, 1973[a]

Treatment[b]	Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %		Yield[c]	
	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	Total, quintal/ha.	U.S. No. 1's, %
	May 28 & 29				August 22					
170 kg/ha. NH_4NO_3	607	36	102	33	11	5	155	120	758	73
170 kg/ha. Urea	416	48	50	46	10	5	93	80	706	71
170 kg/ha. SCU 100	108	47	42	104	6	0	168	-	706	72
170 kg/ha. SCU 45	144	16	60	81	-	-	-	-	706	72
170 kg/ha. SCU 25	101	38	28	0	10	4	150	200	643	69
500 kg/ha. NH_4NO_3	562	50	26	54	123	161	136	71	735	68
500 kg/ha. Urea	326	66	80	79	13	111	131	132	675	68
500 kg/ha. SCU 100	427	97	31	81	132	291	91	35	719	75
500 kg/ha. SCU 45	381	40	65	62	-	-	-	-	731	68
500 kg/ha. SCU 25	273	104	55	114	60	13	127	177	765	67
	July 19				October 16					
170 kg/ha. NH_4NO_3	13	28	79	86	58	22	69	117		
170 kg/ha. Urea	16	44	72	86	121	36	64	96		
170 kg/ha. SCU 100	29	29	83	28	171	17	66	89		
170 kg/ha. SCU 45	-	-	-	-	138	22	78	47		
170 kg/ha. SCU 25	16	34	96	82	209	25	29	55		
500 kg/ha. NH_4NO_3	393	77	70	103	240	91	77	71		
500 kg/ha. Urea	34	324	6	115	107	140	77	94		
500 kg/ha. SCU 100	107	54	49	80	224	114	84	32		
500 kg/ha. SCU 45	-	-	-	-	393	47	108	76		
500 kg/ha. SCU 25	32	37	128	78	115	38	49	57		

[a]Solid-set sprinkler system, silt loam site.

[b]SCU 100, 45 and 25 = sulfur-coated ureas releasing 100%, 45%, and 25% of their N, respectively, during the standard 7-day leaching test. Planted April 19, harvested October 17. Russet Burbank potatoes.

[c]Quintal/hectare = cwt/acre x 1.12.

water standard (107 mg/l) for the high fertilization rate. Even the slow-release N fertilizer produced an average subsoil dissolved-N value nearly 9 times the drinking water standard (86 mg/l) at this site, indicating the importance of sound water management as well as proper fertilizer management if leaching of N is to be controlled.

Little growth response to N fertilization was observed for this site. Total yield values for the two fertilization rates when using traditional N sources averaged 732 and 706 quintal/ha., respectively, with corresponding percentages of U.S. No. 1 tubers of 72 and 68%. Thus, reductions in both total yield and tuber quality occurred with increasing application rates of traditional N fertilizers. However, total yields for the same fertilization rates when using slow-release N fertilizers averaged 684 and 738 quintal/ha., with corresponding percentages of U.S. No. 1 tubers of 71 and 70%. Furthermore, total yield was increased substantially at the higher fertilization rate as the N was more slowly released, with values ranging from 719 quintal/ha. for SCU 100 (the most soluble of the slow-release sources) through 731 quintal/ha. for SCU 45 (a material of intermediate solubility), to 765 quintal/ha. for SCU 25 (the least soluble of the slow-release sources employed). However, the percentage of U.S. No. 1 tubers decreased at the higher fertilization rate as the N was more slowly released. Thus, although a substantial increase in total yield could be obtained from the highest fertilization rate and the most slowly-released form of N, this treatment resulted only in a relatively minor increase in the actual weight of U.S. No. 1 tubers over that produced at lower fertilization rates with traditional N sources.

Average standard deviations expressed as a percentage of the respective means were virtually identical for root zone and subsoil dissolved-N values at this site. Furthermore, no consistent trends with either time, rate, or fertilizer source were observable.

Trends in dissolved-N levels for the surface 30 cm of soil with respect to positioning near the crop row are given in Table A-30. For a given fertilizer source on a given sampling date, average dissolved-N values increased with increasing fertilization rate. Average minimum values for the traditional N sources were in the 10-20 mg/l range, whereas minimum values for the slow-release N sources were in the 20-40 mg/l range (because no uncommonly low values were obtained near season's end in this case). Dissolved-N values for samples taken from the crop row tended to be higher than for samples taken from the irrigation furrow on all sampling dates, which probably reflects both greater evaporation from the crop row between irrigations and a tendency for water to drip off foliage and produce additional leaching in the furrow during irrigation.

Values for standard deviations as a percentage of the means exhibited no consistent trends with position, time, or N source, although slightly higher standard deviations generally occurred for the slow-release N sources than for the traditional sources. Standard deviations for higher rates of fertilization were higher than for lower rates of fertilization early in the season, until the fertilizer band became dissipated by repeated water movement. The standard deviation values were lower than obtained for the furrow-irrigated site near Moses Lake, reflecting the lack of lateral variability associated with the most recent advance of the wetting front on sprinkler-irrigated fields.

Othello station -

Data for slow-release N experiments conducted on the Othello research station in 1973 are given in Tables 32, 33, and A-31. No suspension fertilizer experiments were conducted at this location in 1973. Increasing the N fertilization rate increased the levels of dissolved-N in the root zone for all sampling times and all fertilizer sources. Use of slow-release sources decreased average root zone dissolved-N values in most cases. As stated earlier, an apparent increase in dissolved-N values between the August and October samplings may reflect either upward movement and evaporation of solution at the soil surface after irrigation had ceased, or release of N from crop residues and slow-release fertilizer granules at a rate exceeding the plant uptake rate late in the growing season. Use of slow-release N fertilizer sources produced dissolved-N values only one to two times the maximum permissible drinking water standards for the mid-season samplings at the lowest fertilization rate. Dissolved-N values in the root zone were less than two times the drinking water standard by August 23 for traditional N sources as well, but substantially higher values existed for such sources (15-16 times the drinking water standard) during July.

Average values for dissolved-N below the plant root zone generally were higher for the higher fertilization rate and for the traditional N sources. Use of the lower rate of fertilization produced 3- to 4-fold lower values for dissolved-N below the root zone late in the growing season, and use of slow-release N sources produced an average of a 4-fold lower accumulation of N below the root zone at the higher fertilization rate than did the use of traditional N sources.

Yields were poorly related to N fertilization rate. Average yields for traditional N sources were 616 and 597 quintal/ha., respectively, for the low and high fertilization rates, with comparable values for the

Table 32. DISSOLVED INORGANIC N AND YIELD DATA, SLOW-RELEASE N EXPERIMENTS, OTHELLO STATION, 1973[a]

Treatment[b]	Dissolved N, mg/l 0-60 cm	Dissolved N, mg/l 60+ cm	Std. deviation, % 0-60 cm	Std. deviation, % 60+ cm	Dissolved N, mg/l 0-60 cm	Dissolved N, mg/l 60+ cm	Std. deviation, % 0-60 cm	Std. deviation, % 60+ cm	Yield[c] Total, quintal/ha.	Yield[c] U.S. No. 1's, %
	May 24				August 23					
170 kg/ha. NH_4NO_3	112	11	87	91	24	29	97	83	600	56
170 kg/ha. Urea	156	20	86	15	11	21	107	57	631	61
170 kg/ha. SCU 100	182	26	63	85	18	21	62	52	592	60
170 kg/ha. SCU 25	345	20	119	75	11	13	94	92	719	55
500 kg/ha. NH_4NO_3	191	5	111	-	394	415	78	149	526	61
500 kg/ha. Urea	562	34	121	27	510	52	84	44	668	60
500 kg/ha. SCU 100	294	49	65	122	214	38	74	74	577	62
500 kg/ha. SCU 25	219	27	104	85	182	68	144	122	731	63
	July 10				October 18					
170 kg/ha. NH_4NO_3	210	25	99	76	40	7	67	100		
170 kg/ha. Urea	89	115	106	119	26	8	57	163		
170 kg/ha. SCU 100	27	15	69	80	65	17	79	77		
170 kg/ha. SCU 25	23	23	58	61	71	10	52	106		
500 kg/ha. NH_4NO_3	578	655	84	170	191	171	135	111		
500 kg/ha. Urea	766	36	68	108	340	229	120	106		
500 kg/ha. SCU 100	778	18	81	83	278	82	118	96		
500 kg/ha. SCU 25	148	20	117	120	224	21	133	43		
	July 24									
170 kg/ha. NH_4NO_3	167	16	141	81						
170 kg/ha. Urea	151	78	99	97						
170 kg/ha. SCU 100	27	17	61	100						
170 kg/ha. SCU 25	21	12	51	8						
500 kg/ha. NH_4NO_3	565	25	75	40						
500 kg/ha. Urea	761	22	45	14						
500 kg/ha. SCU 100	592	47	105	123						
500 kg/ha. SCU 25	270	52	97	75						

[a]Rill irrigation, silt loam site.
[b]SCU 100 and SCU 25 = Sulfur-coated ureas releasing 100% and 25% of their N, respectively, during the standard 7-day leaching test. Planted May 1, harvested October 30 and November 2. Russet Burbank potatoes.
[c]Quintal/hectare = cwt/acre x 1.12.

Table 33. ADDITIONAL DISSOLVED INORGANIC N DATA, SLOW-RELEASE N EXPERIMENTS, OTHELLO STATION, 1973[a]

Treatment[b]	Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %	
	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm
	May 24				July 10 (Rows)				October 18			
170 kg/ha. NH_4NO_3	112	11	87	91	210	25	99	76	40	7	67	100
170 kg/ha. $(NH_4)_2SO_4$	217	22	87	109	138	201	135	138	-	-	-	-
170 kg/ha. Urea	156	20	86	15	89	115	106	119	26	8	57	163
170 kg/ha. SCU 100	182	26	63	85	27	15	69	80	65	17	79	77
170 kg/ha. SCU 45	134	16	59	81	213	22	106	46	42	13	63	139
170 kg/ha. SCU 25	345	20	119	75	23	23	58	61	71	10	52	106
					July 10 (Furrows - 170 kg/ha. rate)				July 10 (Furrows - 500 kg/ha. rate)			
340 kg/ha. NH_4NO_3	567	38	152	79	17	13	80	100	47	24	75	121
340 kg/ha. $(NH_4)_2SO_4$	122	17	68	24	43	16	105	88	52	103	103	136
340 kg/ha. Urea	312	34	77	59	34	38	9	47	40	7	58	57
340 kg/ha. SCU 100	291	6	39	133	30	15	104	93	57	25	67	52
340 kg/ha. SCU 45	443	20	108	95	18	6	69	133	23	18	121	139
340 kg/ha. SCU 25	256	30	61	110	8	17	81	94	16	8	50	75
					July 10 (Rows)				October 18			
500 kg/ha. NH_4NO_3	191	5	111	-	578	655	84	170	191	171	135	111
500 kg/ha. $(NH_4)_2SO_4$	120	49	49	114	1050	47	82	70	-	-	-	-
500 kg/ha. Urea	562	34	121	27	766	36	68	108	340	229	120	106
500 kg/ha. SCU 100	294	49	65	122	778	18	81	83	278	82	118	96
500 kg/ha. SCU 45	335	47	85	2	363	21	58	67	286	40	89	81
500 kg/ha. SCU 25	219	27	104	85	148	20	117	120	224	21	133	43

[a]Rill irrigation, silt loam site.
[b]SCU 100, 45 and 25 = sulfur-coated ureas releasing 100%, 45%, and 25%, of their N, respectively, during the standard 7-day leaching test. Planted May 1, harvested October 30 and November 2. Russet Burbank potatoes.

slow-release N sources of 656 and 654 quintal/ha. Thus, slightly higher yields were obtained with slow-release N fertilizers at this location, and the lower rate of N fertilization was adequate for maximum crop yields. The greatest total yields and actual (not percentage) yields of U.S. No. 1 tubers were obtained for the slowest of the two slow-release fertilizers tested.

Additional data on the distribution of dissolved-N for the various fertilizer sources and soil depths are provided in Table 33. This table includes results for three traditional N sources and three slow-release sources, compared to the data on only two sources of each type as listed in Table 32. Little change in dissolved-N levels on May 24 was observed between the 340 and 500 kg N/ha. fertilization rates, and no leaching of N to greater than the 60 cm depth had occurred by this sampling date. By July 10, substantial differences in dissolved-N values were apparent with respect to fertilization rate, N source, and sampling position (crop row vs. irrigation furrow). Markedly lower dissolved-N values for the root zone were obtained for the leached portion beneath the irrigation furrow compared to the zone of solute accumulation in the crop row. However, relatively little difference between the row and furrow sampling locations was evident for soil depths greater than 60 cm. This was particularly true where the rate of N release had been controlled by using slow-release N fertilizer.

By October 18, values for dissolved inorganic N in the plant root zone were only 3 to 6 times the recommended drinking water standard for the lowest N fertilization rate, but were still 26 to 27 times the drinking water standard for the highest fertilization rate. Root zone dissolved-N values were as high or higher for the slow-release N sources by this sampling date, although lower dissolved-N values at the deeper soil depths beneath the slow-release N plots verified that less leaching of N had occurred in this case during the preceeding crop growth period.

No consistent differences in standard deviations (expressed as percentages of the respective means) were evident between values for the plant root zone and those for the lower soil profile, with averages for the two depths of 91% and 85% of the mean, respectively. Slightly more variation occurred for the higher fertilization rate and for the traditional N sources in most cases. Standard deviations of 90% to 94% of the mean concentrations were observed for the traditional N sources, compared to values of 82% to 88% of the respective means for the slow-release N sources.

Table A-31 summarizes variations in dissolved-N levels in the surface 30 cm of soil at this location for various N sources, sampling periods, and sampling positions with respect to the crop row. In all cases, higher dissolved-N levels were observed for the higher fertilization rate. Dissolved-N values were highest for the crop row and lowest for the irrigation furrow on three of the four sampling dates for this furrow-irrigated field. On the fourth date (August 10), highest values actually were observed for the irrigation furrows. This reflects the alternate-furrow irrigation employed, with much of the sampling on this date apparently associated with crop rows which had recently been flushed free of salt by the lateral flow of the irrigation wetting front. There was a definite tendency for the percent standard deviation for the irrigation furrow (40%) to be lower than that for the crop row (70%) or for the region half-way between the row and the furrow (65%).

Petiole Nitrate-N vs. Soil Test Nitrogen as Yield Predictors

Soil samples from the 0 to 30-cm soil depth in the crop row, the furrow, and half-way between at the Moses Lake, Othello area, and Othello Station locations were tested as predictors of crop yields for the 1973 season. Petiole nitrate-N levels from the same experimental plots also were tested as yield predictors for the same period. Results of the petiole analyses are presented in Table 34.

Petiole nitrate-N levels generally increased with increasing N fertilization rate, and decreased with time, at all experimental locations. Lower petiole nitrate-N levels generally accompanied the use of slow-release N fertilizers (compared to traditional N sources). This is consistent with results of the soil analyses reported previously. An exception to the trend with increasing fertilization rate occurred for the 340 kg N/ha. treatment of the suspension fertilizer experiments at the Moses Lake location. Many of the plots from this particular treatment were located near the head of the furrow-irrigated field, and hence were subject to excessive leaching. Thus, the "effective" fertilization rate for this treatment was less than the "anticipated" fertilization rate.

An exception to the normal time trend occurred as well at the Moses Lake location, for the banded application of the suspension fertilizer experiment. This may reflect decreased availability to the plant of N in the concentrated fertilizer band, due to osmotic effects, until the band became more diffuse later in the growing season. Petiole nitrate-N levels for the Moses Lake location were well below the normally-accepted minimum safe tissue level of 5,000 to 10,000 ppm throughout most of the sampling period. Vines died by mid-August at this location, probably from N stress resulting from excessive leaching of nitrate even during alternate-furrow irrigation at this extremely sandy site.

Table 34. PETIOLE NITRATE-N LEVELS, SUSPENSION FERTILIZER AND SLOW-RELEASE N EXPERIMENTS, 1973

(ppm, dry-weight basis)

Location	Days Since Planting	Suspension fertilizer experiments								Slow-release nitrogen experiments					
		Broadcast				Banded				Traditional			Slow-Release		
Moses Lake area		110 kg/ha.	220	340	450	110	220	340	450 kg/ha.	170 kg/ha.	280	390	170	280	390 kg/ha.
	90	640	1840	840	3740	140	250	240	390	620	2120	5170	730	1120	1550
	104	660	1170	740	2130	360	500	520	460	620	1230	2020	630	960	1380
Othello area		110 kg/ha.	220	340	450	110	220	340	450 kg/ha.	170 kg/ha.	340	500	170	340	500 kg/ha.
	90	-	-	-	-	-	-	-	-	7550	15000	16900	3120	11300	16200
	108	5140	7190	4110	4360	5220	5410	6020	3580	-	-	-	-	-	-
	115	-	-	-	-	-	-	-	-	5290	11800	14200	3890	8800	13300
	125	-	-	-	-	-	-	-	-	4870	6780	5140	6750	5220	6470
	132	-	-	-	-	-	-	-	-	2600	4950	7940	1970	4500	6530
	134	3650	5040	2760	2240	3240	4290	3180	2060	-	-	-	-	-	-

Location	Days Since Planting	Maturity study								Slow-release nitrogen experiments					
		Check				Vine Kill				Traditional			Slow-Release		
Othello station		220 kg/ha.	340	450	560	220	340	450	560 kg/ha.	170 kg/ha.	340	500	170	340	500 kg/ha.
	85	12400	13200	14000	13500	13300	13000	14500	14100	7350	13000	14700	7070	10400	13400
	98	12200	15700	16900	18700	13000	16500	16700	18300	8810	13300	17400	7550	11500	14500
	111	7230	11700	13700	14500	8380	12000	13700	14600	5990	9690	13200	4740	9110	11600
	133	5140	8720	11400	13400	6100	9640	11400	12800	2850	6160	9450	3110	5280	8620

Although sampling of the suspension fertilizer experiment in the Othello area was limited, a decrease in petiole nitrate-N levels at the higher N fertilization rates consistently appeared. This could also be explained as the result of limited N uptake from highly concentrated suspension fertilizer zones, although greater differences between broadcast and banded treatments, and similar effects for higher application rates of traditional (dry) fertilizers to the slow-release N experiments, would be expected as well.

As the "check" and "vine kill" plots of the Othello Station maturity study were treated identically until the end of the growing season, differences between the two illustrate the cumulative results of sampling and analytical errors. As can be seen from the data, such errors generally were small, averaging only 5.0 percent of the mean petiole nitrate-N levels in this case.

Results from the correlation of petiole nitrate-N or surface soil dissolved inorganic N levels with crop yield and quality are given in Table 35. Petiole nitrate-N and surface soil (e.g., root zone) dissolved-N were well correlated for the slow-rlease N experiments (with the exception of one sampling date for the Othello area location) and for the maturity study at the Othello station. The two parameters were poorly correlated for the suspension fertilizer experiments. As indicated above, this may have resulted from low uptake of N from banded fertilizer plots at the higher fertilization rates, despite high soil dissolved-N levels, due to osmotic effects on roots near the highly concentrated fertilizer band.

Total yield and yield of U.S. No. 1 tubers were well correlated with soil dissolved-N levels for both sets of experiments at the Moses Lake location in 1973, reflecting the N stress at this location due to excessive leaching of nitrate. Positive correlations between total yield, tuber quality, and petiole nitrate-N levels also were obtained for the slow-release N experiments at this location, although negative correlations were obtained between petiole nitrate-N, total yield and tuber quality for the suspension fertilizer experiments. This reflects higher yields at the higher fertilization rates in these experiments, despite lower petiole nitrate-N levels on both sampling dates. The lower petiole nitrate-N values may reflect early season inhibited root activity near the fertilizer band (as discussed previously), with the higher fertilization rates leading to more nearly adequate late-season soil N levels at this heavily-leached location.

Poor correlations between total yield, tuber quality, and either petiole nitrate-N or surface-soil dissolved-N were obtained for each of the other experimental locations. This reflects the abundance of

Table 35. CORRELATION[a] OF SOIL DISSOLVED INORGANIC N AND PETIOLE NITRATE-N WITH POTATO YIELD AND QUALITY, 1973

Location	Days after planting	Petiole NO_3-N vs soil N		Total yield vs soil N		Total yield vs petiole NO_3-N		Yield U.S. No. 1's vs soil N		Yield U.S. No. 1's vs petiole NO_3-N	
Moses Lake area		Susp.	Slow N	Susp.	Slow N	Susp.	Slow N	Susp.	Slow N	Susp.	Slow N
	90	.183	.902	.671	.694	-.482	.504	.458	.604	-.531	.492
	104	-.150	.753	.784	.760	-.477	.365	.625	.659	-.508	.463
Othello area		Susp.	Slow N	Susp.	Slow N	Susp.	Slow N	Susp.	Slow N	Susp.	Slow N
	89	-	.863	-.356	-.090	-	.281	-.244	-.253	-	.105
	109	-.648	.823	-.088	-.053	.062	.256	.061	-.165	-.185	.044
	123	-	.089	-.059	.345	-	-.156	.046	.016	-	-.072
	132	-.672	.712	-.070	.184	.054	.259	.073	.135	-.198	.028
Othello station		Matur	Slow N	Matur	Slow N	Matur	Slow N	Matur	Slow N	Matur	Slow N
	86	.722	.882	-.734	-.590	-.432	-.504	-.722	-.402	-.442	-.369
	100	.982	.990	-.732	-.330	-.575	-.461	-.732	-.124	-.594	-.326
	113	.913	.898	-.710	-.326	-.528	-.395	-.733	-.043	-.537	-.237
	128	.996	.944	-.743	-.319	-.577	-.369	-.734	-.073	-.602	-.243

[a]Linear correlation coefficients.

available N present at these locations, so that crop yield frequently was depressed at the higher fertilization rates. In fact, strong negative correlations between crop yield or quality and soil or plant N levels were obtained in several cases at these sites.

From these studies it appears that petiole nitrate-N or surface soil dissolved-N levels have only limited values as predictors of crop yield or tuber quality on recropped potato lands (or other lands of high residual soil N levels) in the Columbia Basin. They are of value as predictors primarily on N-stressed areas (such as the furrow-irrigated, sandy Moses Lake location). They certainly do not answer the whole question of predicting crop N needs (and hence minimizing N leaching losses) for this area.

Nitrogation Experiment, Othello Station

Another set of experiments at the Othello Station during the 1973 season involved application of fertilizer through the sprinkler line ("nitrogation") at various fertilization rates and application intervals. Results of these experiments are given in Table 36.

Mid-season (July 6) values for dissolved inorganic N in the root zone and subsoil did not vary consistently. Root zone N values were highest for the least heavily-fertilized plots, which probably reflects high early-season variability remaining from the low levels of N banded to all plots at planting time. Subsoil N values appear to reflect accumulations from prior cropping of the experimental area. Root zone dissolved-N levels by late season (August 28) and season's end (October 18) generally were higher for the higher fertilization rates and for the less-frequent fertilization intervals. Yield levels were highest for the lower fertilization rate (consistent with other results suggesting an excess of N in many fields of the Columbia Basin area) and the most frequent application interval. The merit of continuously "feeding" the potato crop with adequate, although not excessive, quantities of fertilizer N through the sprinkler system appears obvious from these data. Levels of dissolved inorganic N in the root zone and subsoil from such fields appear to be relatively insensitive to fertilization rate or application interval. However, little evidence of substantial leaching of N was apparent, even at high fertilization rates and for long application intervals.

Table 36. DISSOLVED INORGANIC N AND YIELD DATA, NITROGATION EXPERIMENT, OTHELLO STATION, 1973[a]

Treatment	Dissolved N, mg/l		Std. deviation, %		Dissolved N, mg/l		Std. deviation, %		Yield[b]	
	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	0-60 cm	60+ cm	Total, quintal/ha.	U.S. No. 1's, %
	July 6				October 18					
340 kg N/ha., 2 week interval	98	67	124	66	75	24	47	50	775	69
340 kg N/ha., 4 week interval	234	179	89	60	87	50	71	69	643	71
340 kg N/ha., 6 week interval	60	22	83	59	115	53	49	32	709	77
670 kg N/ha., 2 week interval	17	20	88	50	115	34	60	102	644	70
670 kg N/ha., 4 week interval	9	17	75	112	61	14	58	83	704	76
670 kg N/ha., 6 week interval	27	2	86	150	129	12	69	95	582	68
	August 28									
340 kg N/ha., 2 week interval	18	34	47	124						
340 kg N/ha., 4 week interval	39	25	55	44						
340 kg N/ha., 6 week interval	73	44	60	64						
670 kg N/ha., 2 week interval	46	24	56	104						
670 kg N/ha., 4 week interval	42	28	59	82						
670 kg N/ha., 6 week interval	105	26	48	92						

[a] Solid-set sprinkler system, silt loam site.

[b] Quintal/hectare = cwt/acre x 1.12.

Sprinkler Irrigation Rate Experiment, Othello Station

In a final experiment at the Othello Station for 1973, dissolved inorganic soil N, crop yield, and tuber quality were assessed as a combined function of N fertilization and sprinkler irrigation rates. Irrigation was based on micrometeorological measurements at levels of 75%, 100% (assumed optimum), and 150% of estimated crop evapotranspiration needs. Results are given in Table 37.

Soil solution dissolved-N levels generally increased with increasing N fertilization rate. Early season (May 29) subsoil N values increased with increasing irrigation rate, suggesting some early-season leaching of N at the higher rates. By midseason (July 6), however, N had leached below the root zone even at the lowest irrigation rate, and by late season (August 28) and season's end (September 27), N had been leached from the entire soil profile at the highest irrigation rates, completely reversing the early-season trends. Subsoil dissolved-N concentrations by season's end were decreased by leaching even at the lowest irrigation rate, reflecting a common tendency to over-irrigate late in the season, when plant evaporative needs begin to decrease. Crop yield generally was higher at the higher fertilization and water application rates. Tuber quality increased slightly with increasing irrigation rate, but appeared to be unaffected by fertilization rate.

Good water management appears essential in the prevention of N leaching on silt loam soils of the Columbia Basin, even as it was for the sandy site studied in 1970 and 1971. However, actual potato production on the finer-textured sites appears to be slightly less dependent on water application rates. This may be due to the greater water storage capacities of such soils, and to a tendency for additional water to substitute for leached N to a limited extent during potato tuber production.

Soil Solution Extraction Cup Values, Othello Station

Extraction cup data for the Othello Station in 1973 were limited to a few sites in the nitrogation and sprinkler irrigation rate experiments. Results of these measurements are given in Table 38. The data generally confirmed the soil sampling information, but results were more variable, because of the failure to obtain samples from all sites on all sampling dates. The extraction cup program had, in general, been phased out by this time, so no attempt was made to provide the cups with the extensive attention needed to keep all of them operative throughout the entire season.

Table 37. DISSOLVED INORGANIC N AND YIELD DATA, SPRINKLER IRRIGATION RATE EXPERIMENT, OTHELLO STATION, 1973[a]

Treatment	Dissolved N, mg/l 0-60 cm	Dissolved N, mg/l 60+ cm	Std. deviation, % 0-60 cm	Std. deviation, % 60+ cm	Dissolved N, mg/l 0-60 cm	Dissolved N, mg/l 60+ cm	Std. deviation, % 0-60 cm	Std. deviation, % 60+ cm	Yield[b] Total, quintal/ha.	Yield[b] U.S. No. 1's, %
	May 29				August 28					
75% ET[c], 220 kg N/ha.	292	3	128	133	33	51	46	73		
75% ET, 670 kg N/ha.	296	9	141	89	164	356	157	105		
100% ET, 220 kg N/ha.	594	26	91	69	9	12	104	92		
100% ET, 670 kg N/ha.	1317	22	87	64	53	287	168	119		
150% ET, 220 kg N/ha.	443	35	74	57	14	9	62	67		
150% ET, 670 kg N/ha.	1222	62	58	118	24	90	77	174		
	July 6				September 27					
75% ET, 110 kg N/ha.	-	-	-	-	33	8	101	128	638	75
75% ET, 220 kg N/ha.	135	21	43	105	55	18	55	93	610	74
75% ET, 450 kg N/ha.	-	-	-	-	284	75	92	186	740	74
75% ET, 670 kg N/ha.	436	352	106	121	347	162	139	129	666	74
100% ET, 110 kg N/ha.	-	-	-	-	18	8	71	160	631	74
100% ET, 220 kg N/ha.	52	30	102	100	12	6	58	100	652	76
100% ET, 450 kg N/ha.	-	-	-	-	16	86	90	121	657	79
100% ET, 670 kg N/ha.	369	77	113	97	23	146	101	177	672	77
150% ET, 110 kg N/ha.	-	-	-	-	28	13	22	24	711	76
150% ET, 220 kg N/ha.	161	66	158	155	29	13	83	39	635	81
150% ET, 450 kg N/ha.	-	-	-	-	27	29	55	70	706	76
150% ET, 670 kg N/ha.	733	249	70	221	31	24	78	46	640	75

[a]Solid-set sprinkler irrigation, silt loam site.
[b]Quintal/hectare = cwt/acre x 1.12.
[c]ET = evapotranspiration by the crop, as estimated from micrometeorological measurements.

Table 38. DISSOLVED INORGANIC N, EXTRACTION CUP VALUES, OTHELLO STATION, 1973[a]

Experiment and treatment	Depth	June 11	June 21	July 6	July 14	July 18	July 25	Aug. 10	Aug. 29
Nitrogation									
340 kg N/ha., 2 week interval	Top 60 cm	510	-	-	-	13	8	9	267
340 kg N/ha., 2 week interval	Lower Profile	91	-	-	-	-	-	-	-
340 kg N/ha., 6 week interval	Top 60 cm	72	-	-	13	13	23	15	125
340 kg N/ha., 6 week interval	Lower Profile	0	-	-	4	7	8	16	225
670 kg N/ha., 2 week interval	Top 60 cm	140	290	4	0	0	12	11	90
670 kg N/ha., 2 week interval	Lower Profile	34	45	41	18	24	-	-	12
670 kg N/ha., 6 week interval	Top 60 cm	304	35	670	1	0	0	3	163
670 kg N/ha., 6 week interval	Lower Profile	83	18	-	-	6	-	-	2
Sprinkler rate									
220 kg N/ha., 75% ET[b]	Top 60 cm	457	189	1	150	167	178	61	35
220 kg N/ha., 75% ET	Lower Profile	63	25	7	26	0	3	8	0
670 kg N/ha., 75% ET	Top 60 cm	133	586	118	24	55	181	-	82
670 kg N/ha., 75% ET	Lower Profile	14	112	29	509	391	902	-	31
450 kg N/ha., 100% ET	Top 60 cm	-	50	53	292	311	328	354	248
450 kg N/ha., 100% ET	Lower Profile	-	-	-	-	-	-	-	-
220 kg N/ha., 150% ET	Top 60 cm	645	-	-	4	18	31	21	3
220 kg N/ha., 150% ET	Lower Profile	11	-	-	48	66	28	34	45
670 kg N/ha., 150% ET	Top 60 cm	1217	968	1387	394	289	110	83	108
670 kg N/ha., 150% ET	Lower Profile	53	94	12	20	24	39	26	14

[a]Solid-set sprinkler system, silt loam site.

[b]ET = crop evapotranspiration, as estimated from microclimatological measurements.

Soil solution samples from the nitrogation experiments supplemented the soil sampling program nicely and demonstrated the low dissolved-N levels possible with this approach. Values tended to increase markedly by late season, as plant N needs diminished. Limited soil solution sampling should prove useful in "nitrogated" fields to permit better cutoff of fertilization as plant needs decrease.

Results from the sprinkler-irrigation rate plots were less definitive. Higher soil solution N values were obtained, in general, from the more heavily-fertilized plots, but this trend was marked, in many cases, by failure of the extraction cups to accurately sample the highest concentrations of dissolved-N in the profile, because of "peaks" of dissolved-N between extraction cup depths. Considerable N from the 670 kg/ha. plots was evident for the deepest extraction cups in the low water application rate plots, but similar high concentrations of N were never observed for the deepest cups in the high water application rate plots. The greater amount of leaching in the latter plots could have kept the N flushed from the lower subsoil region if most of the deeper cups were placed immediately above a soil layer limiting water movement, but such flushing should also have been evident from the soil sampling data for the same plots. The results can only be regarded as an unexplained anomaly at present.

1974 SEASON

Because of a large backlog of accumulated analyses, only two small experiments and two supplemental samplings for additional data on the Othello Station were conducted in 1974. Results from these studies are presented below.

Petiole Nitrogen Experiment

In one small experiment conducted on the Othello Station, total yield and tuber quality were determined for plots maintained at approximately constant petiole nitrate-N levels throughout the growing season. Results of petiole analyses for samples from these plots are given in Tables 39 and 40.

The range in petiole N values over the selected fertilization rates was not as great as had been expected (Table 39). The experimental field had been maintained in alfalfa for 3 years prior to the 1973 season, and N released from soil organic matter and crop residues,

Table 39. SUMMARIZED PETIOLE ANALYSES, BY FERTILIZATION RATE, PETIOLE N EXPERIMENT, OTHELLO STATION, 1974[a]

Date	Days since planting	NITROGEN				POTASSIUM				CALCIUM				PHOSPHORUS			
		N1[b]	N2	N3	N4	N1	N2	N3	N4	N1	N2	N3	N4	N1	N2	N3	N4
6-12	70	3.2	3.3	3.2	3.4	10.2	10.1	9.8	9.9	2.1	2.0	2.2	2.1	.43	.41	.38	.43
6-26	84	2.7	2.8	2.7	3.1	9.0	9.5	9.4	9.6	2.3	2.2	2.2	2.1	.51	.49	.46	.48
7- 1	90	2.4	2.5	2.5	2.8	-	-	-	-	2.1	2.0	2.2	2.0	.41	.45	.40	.44
7- 9	98	2.1	2.2	2.6	2.7	8.0	8.1	8.2	8.3	2.2	2.3	2.1	2.0	.43	.44	.42	.43
7-15	104	1.9	2.0	2.2	2.6	7.5	7.9	7.5	8.3	2.3	2.3	2.2	2.1	.35	.35	.34	.39
7-23	112	1.9	2.0	2.2	2.8	7.6	7.4	7.2	7.7	2.0	2.1	2.1	1.9	.30	.32	.27	.31
7-29	118	1.8	2.1	2.1	2.7	7.1	6.8	6.2	7.3	3.0	2.8	2.7	2.4	.27	.30	.28	.33
8- 5	125	1.6	1.9	2.0	2.5	6.2	6.7	6.5	7.3	2.4	2.1	2.3	1.8	.26	.27	.23	.26
8-11	131	1.5	1.7	1.7	2.4	7.0	6.4	6.0	7.4	2.4	2.1	2.2	1.7	.21	.23	.21	.26
8-18	138	0.7c	0.6c	1.2c	2.8c	6.4	6.2	6.2	7.6	2.9	2.5	2.5	1.9	.20	.21	.20	.26
8-30	150	0.5c	0.4c	0.9c	1.6c	6.8	7.2	6.4	8.8	2.8	2.4	2.3	1.7	.20	.21	.18	.26
9- 4	155	1.0c	1.3c	1.7c	3.1c	7.2	7.2	6.7	8.5	2.8	2.5	2.4	1.8	.19	.21	.17	.26
9- 9	160	-	1.1c	1.4c	2.7c	-	7.6	6.2	8.1	-	2.3	2.4	1.7	–	.19	.16	.23
9-18	169	-	-	1.6c	2.9c	-	-	6.3	8.5	-	-	2.4	1.9	–	–	.18	.20

[a]Solid-set sprinkler irrigation, silt loam site.

[b]N1, N2, N3, and N4 = constant petiole nitrate-N levels, maintained by adding 90, 170, 410, and 540 kg N/ha.

[c]= estimated from corresponding nitrate-N values.

Table 40. SUMMARIZED PETIOLE ANALYSES, BY VARIETY, PETIOLE N EXPERIMENT, OTHELLO STATION, 1974[a]

(% dry weight)

Treatment[b]	Norgold May 16	Norgold June 26	Norgold July 23	Norgold Aug. 30	Russet Burbank May 16	Russet Burbank June 26	Russet Burbank July 23	Russet Burbank Aug. 30
	Norgold				Russet Burbank			
Sprinkler-irrigated plots								
N1D1	76.8	9.4	2.9	0.0	30.2	21.2	0.0	0.0
N1D2	93.8	31.0	31.3	7.4	179.1	20.7	62.4	26.8
N1D3	210.7	172.3	138.5	94.0	131.1	138.9	410.0	208.4
N1D4	720.2	215.2	144.7	301.2	567.3	331.3	195.0	684.7
N2D1	125.5	22.1	11.5	0.0	138.9	19.9	36.0	0.0
N2D2	146.1	97.9	386.8	11.8	165.0	64.6	21.9	7.2
N2D3	279.9	237.4	113.4	85.7	114.6	184.4	152.3	270.7
N2D4	168.5	607.8	403.0	397.8	192.8	155.7	126.3	272.0
	Kennebeck				Russet Burbank			
Furrow-irrigated plots								
P1D1	--	34.3	45.0	19.4	--	228.3	107.8	82.2
P1D2	--	208.2	301.3	202.3	--	137.7	174.0	112.9
P1D3	--	194.7	87.8	253.0	--	376.4	244.8	83.9
P1D4	--	466.7	351.1	785.2	--	445.0	286.2	1203.1
P2D1	--	36.0	79.6	0.0	--	55.5	71.9	329.9
P2D2	--	175.2	53.7	54.5	--	198.5	272.2	54.3
P2D3	--	226.9	83.5	212.9	--	189.3	213.2	326.6
P2D4	--	977.6	427.9	361.6	--	718.6	356.9	438.3

[a]Silt loam site.

[b]N1 = 220 kg N/ha., N2 = 450 kg N/ha., P1 = 38,000 plants, ha., P2 = 55,500 plants/ha., D1 = 4.5 kg Di-syston (actual)/ha., D2 = 9 kg Di-Syston/ha., D3 = 18 kg Di-Syston/ha., D4 = 36 kg Di-Syston/ha.

coupled with the 90 kg N/ha. banded at the time of planting, was sufficient to maintain fairly high nitrate-N and total N levels in the petioles throughout the growing season even at the lowest fertilization rate. Similarly, maintenance of the highest specified nitrate-N level throughout the season proved difficult, even with the addition of nearly 560 kg N/ha. to each experimental plot. However, the spread in average petiole total N levels during the period from July 1 to September 1 was reasonably good, with average values for the four N levels of 1.6%, 1.7%, 1.9%, and 2.5%, respectively. Average petiole calcium values tended to decrease with increasing N fertilization rate for the same period (possibly due to enhanced growth accompanied by a nutrient dilution effect), but neither the average phosphorus nor the average potassium values varied consistently with N fertilization rate. Average levels of petiole N did not vary consistently between varieties (Table 40), although Russet Burbank petioles maintained higher N levels late in the season than did either Kennebeck or Norgold Russet petioles. Kennebeck petioles maintained higher average levels of potassium and phosphorus, but lower levels of calcium, than did petioles from the other varieties. The relative trends with respect to these nutrients were reversed for Norgold Russet petioles, with Russet Burbank petioles exhibiting intermediate average levels of all three nutrients.

Yield data for the 1974 petiole N experiments are summarized in Tables 41-43. Total yields generally were highest for the Kennebeck variety and considerably lower for the Norgold Russet variety (Table 41). Russet Burbank yields generally were similar to, but slightly lower than, those of the Kennebeck variety. Percentages of U.S. No. 1 tubers consistently were similar for the Kennebeck and Norgold Russet varieties, but substantially lower for the Russet Burbank variety. Yields of U.S. No. 1 tubers followed the same relative order as observed for total yields, although levels for Russet Burbank were more similar to those of Norgold Russet than of Kennebeck in this case.

Total yields in all cases remained constant or even decreased as a function of N fertilization rate except for the highest fertilization rate, where a substantial increase in total yield was obtained (Table 41). Percentage of U.S. No. 1 tubers remained essentially invariant with increasing N fertilization rate. Total yield of Russet Burbank tubers tended to increase, and percentage of U.S. No. 1 tubers tended to decrease, with increasing petiole nitrate-N levels as determined 90 days after planting. However, the trend was less

Table 41. YIELD DATA, PETIOLE N EXPERIMENT, OTHELLO STATION, 1974[a]

Variety	Total yield, quintal/ha. N1	N2	N3	N4	U.S. No. 1's, % N1	N2	N3	N4
Based on plot fertilization rates								
Norgold	538	520	520	557	77	77	81	76
Kennebeck	777	719	750	837	75	79	77	78
R. Burbank	735	731	744	800	63	67	65	58
	L1	L2	L3	L4	L1	L2	L3	L4
Based on petiole nitrate-N levels at 90 days								
Norgold	507	547	536	535	81	80	78	77
Kennebeck	-	805	823	748	-	78	76	72
R. Burbank	661	734	796	-	66	63	60	-
Based on petiole NO_3-N levels at 120 days:								
Norgold	531	536	535	539	74	76	80	79
Kennebeck	836	756	731	827	80	72	81	77
R. Burbank	732	753	700	809	61	65	67	60
Based on petiole NO_3-N levels at 150 days:								
Norgold	-	-	-	-	-	-	-	-
Kennebeck	774	811	849	875	77	63	80	68
R. Burbank	776	710	836	718	65	67	65	51

[a]Solid-set sprinkler irrigation, silt loam site.

[b]N1-4 = 90, 170, 410, and 540 kg N/ha., respectively; L1-4 = <8,000, 8,000-11,000, 11,000-14,000, and >14,000 ppm nitrate-N, respectively, at 90 days; L1-4 = <4,000, 4,000-8,000, 8,000-12,000 and >12,000 ppm nitrate-N, respectively, at 120 days; L1-4 = <2,000, 2,000-4,000, 4,000-6,000, and >6,000 ppm, respectively, at 150 days.

Table 42. YIELD DATA CORRELATED WITH PETIOLE NITRATE LEVELS FOR ENTIRE SEASON, PETIOLE N EXPERIMENT, OTHELLO STATION, 1974[a]

Variety	Total yield, quintal/ha.[b] 0 days	1-20	21-40	41-60	61-80	81+ days	U.S. No. 1's, % 0 days	1-20	21-40	41-60	61-80	81+ days
Based on days petiole nitrate-N below 10,000 ppm												
Norgold	-	547	512	534	-	-	-	79	82	77	-	-
Kennebeck	875	-	781	848	768	978	68	-	79	77	74	82
R. Burbank	-	759	827	721	745	780	-	50	60	59	67	64
Based on days petiole nitrate-N below 7,500 ppm												
Norgold	505	547	544	536	-		77	80	77	76	-	
Kennebeck	875	781	986	730	829		68	79	81	71	79	
R. Burbank	861	764	724	748	752		52	58	64	70	65	
Based on days petiole nitrate-N below 5,000 ppm												
Norgold	511	563	506	-	-		78	81	72	-	-	
Kennebeck	768	943	689	811	978		74	80	73	76	82	
R. Burbank	757	767	738	731	819		56	70	67	65	64	

	Total yield, quintal/ha. Greater than 10 days 10,000 ppm	7,500 ppm	5,000 ppm	Less than 10 days 10,000 ppm	7,500 ppm	5,000 ppm
Based on recovery period after falling below a specified petiole nitrate-N level						
Norgold	595 (81)[c]	607 (82)	570 (81)	552 (82)	560 (79)	568 (77)
Kennebeck	859 (81)	765 (80)	837 (79)	707 (68)	814 (79)	781 (79)
R. Burbank	780 (61)	749 (63)	776 (69)	747 (70)	819 (64)	672 (60)

[a]Solid-set sprinkler irrigation, silt loam site.
[b]Quintal/hectare = cwt/acre x 1.12.
[c]Values in parentheses denote U.S. No. 1 tubers, %.

Table 43. YIELD DATA CORRELATED WITH PETIOLE NITRATE LEVELS PRIOR TO AUGUST 15, PETIOLE N EXPERIMENT, OTHELLO STATION, 1974[a]

Variety	Total yield, quintal/ha.[b] 0 days	1-20	21-40	41-60	U.S. No. 1's, % 0	1-20	21-40	41-60
Based on days petiole nitrate-N below 10,000 ppm								
Norgold	469	560	-	534	76	81	-	77
Kennebeck	812	848	759	802	75	80	71	77
R. Burbank	759	-	787	738	50	-	66	65
Based on days petiole nitrate-N below 7,500 ppm								
Norgold	493	588	522	-	78	81	75	-
Kennebeck	856	730	829	-	77	71	79	-
R. Burbank	787	738	-	748	53	68	-	64
Based on days petiole nitrate-N below 5,000 ppm								
Norgold	511	563	528	-	79	77	79	-
Kennebeck	856	752	883	-	77	74	80	-
R. Burbank	758	736	775	732	61	66	67	61

	Total yield, quintal/ha.					
	Greater than 10 days			Less than 10 days		
	10,000 ppm	7,500 ppm	5,000 ppm	10,000 ppm	7,500 ppm	5,000 ppm
Based on recovery period after falling below a specified petiole nitrate-N level						
Norgold	566 (81)[c]	607 (82)	570 (81)	552 (82)	519 (77)	514 (73)
Kennebeck	859 (81)	731 (81)	729 (78)	729 (62)	529 (78)	-
R. Burbank	787 (66)	773 (70)	767 (67)	747 (70)	722 (60)	697 (59)

[a]Solid-set sprinkler irrigation, silt loam site.
[b]Quintal/hectare = cwt/acre x 1.12.
[c]Values in parentheses denote U.S. No. 1 tubers, %.

consistent for data from the 120-day and 150-day sampling periods, except for the effect on tuber quality at high petiole nitrate-N levels. Total yield of Kennebeck tubers tended to increase with increasing petiole nitrate-N levels for the 150-day petiole sampling, and percentage of U.S. No. 1 tubers tended to decrease at the highest petiole nitrate-N level in all cases for the Norgold Russet and Kennebeck varieties. However, no other consistent trends were evident from the data.

In an attempt to better isolate "critical" petiole nitrate-N levels for optimum growth of the potato varieties studied, individual plot yield data were segregated on the basis of cumulative time for which petiole nitrate-N analyses fell below predetermined levels. These results are given in Tables 42 (where petiole analyses for the entire season were considered) and 43 (where only petiole analyses for samples taken prior to August 15 were considered). The latter approach was an attempt to eliminate late-season petiole samplings, which frequently are regarded as having only limited value in yield predictions. In neither case did any of the petiole nitrate-N levels examined (10,000, 7,500, or 5,000 ppm) appear to be "critical" for high-level production of good-quality tubers. If a "critical" petiole nitrate-N concentration existed for tuber production at this location in 1974, it was below the 5,000 ppm level. At the bottom of each table, total yield and tuber quality are compared for various lengths of recovery period (i.e.,at higher petiole nitrate-N levels) after petiole results had fallen below a specified nitrate-N level. Slightly higher yields generally were obtained for the longer recovery periods, but no adverse effects on quality (e.g.,knobbiness) was evident for samples from plots where petiole nitrate-N levels fell below any of the tested "critical" levels and then returned to higher values for a sustained period.

No adverse effects on total yield or yield of U.S. No. 1 tubers appeared to be associated with petiole nitrate-N levels of 10,000, 7,500, or 5,000 ppm at this location in 1974.

Di-Syston Experiments

In a second set of experiments at the Othello Station in 1974, effects of high application rates of Di-Syston (a systemic insecticide) on yield and tuber quality were assessed. Results from this experiment are summarized in Tables 44-47.

To determine the rate of Di-Syston degradation when large quantities of the insecticide were applied in the fertilizer band at the time of planting, soil samples of constant volume from the immediate vicinity of the fertilizer band were taken from selected plots at approximately

Table 44. DI-SYSTON ANALYSES, DI-SYSTON EXPERIMENT, OTHELLO STATION, 1974[a]

(ppm, soil basis)

Date	Days after planting	NITROGEN			POTASSIUM			CALCIUM			PHOSPHORUS		
		Ken	Nor	Bur	Ken	Nor	Bur	Ken	Nor	Bur	Ken	Nor	Bur
6-12	70	3.3	3.2	3.1	10.7	9.4	9.9	1.7	2.2	2.5	.49	.35	.40
6-26	84	3.0	3.0	2.4	10.3	9.2	8.7	1.7	2.5	2.5	.60	.45	.40
7- 1	90	2.7	2.7	2.2	-	-	-	1.5	2.2	2.5	.51	.41	.36
7- 9	98	2.4	2.4	2.4	8.7	8.2	7.5	1.8	2.4	2.2	.48	.41	.41
7-15	104	2.1	2.2	2.2	8.8	6.8	7.9	1.8	2.5	2.5	.40	.32	.34
7-23	112	2.1	2.1	2.5	8.7	6.5	7.2	1.6	2.3	2.1	.34	.25	.30
7-29	118	2.1	2.1	2.4	8.2	5.6	6.6	2.2	3.3	2.7	.34	.25	.29
8- 5	125	1.8	2.0	2.2	7.8	5.6	6.6	1.8	2.7	2.0	.29	.22	.26
8-11	131	1.7	1.8	2.0	7.3	5.5	7.4	1.6	2.7	2.0	.24	.21	.24
8-18	138	1.1 c	1.4c	1.5c	7.2	5.4	7.3	2.0	3.1	2.2	.23	.20	.22
8-30	150	0.7 c	-	1.0c	7.2	-	7.4	2.3	-	2.3	.21	-	.22
9- 4	155	1.4 c	-	2.1c	7.4	-	7.4	2.2	-	2.5	.20	-	.21
9- 9	160	1.4 c	-	2.1c	7.2	-	7.4	2.1	-	2.2	.19	-	.19
9-18	169	1.8 c	-	2.7c	7.3	-	7.5	2.1	-	2.2	.20	-	.18

[a]Solid-set sprinkler irrigation, silt loam site.

[b]Ken = Kennebeck, Nor = Norgold, Bur = Russet Burbank.

c= estimated from corresponding nitrate-N values.

Table 45. YIELD DATA, DI-SYSTON EXPERIMENTS, OTHELLO STATION, 1974[a]

Variety and treatment	Total yield, quintal/ha.[b] D1[c]	D2	D3	D4	U.S. No. 1's, % D1	D2	D3	D4
Sprinkler-irrigated plots								
Norgold								
220 kg N/ha.	615	578	603	631	78	78	75	77
450 kg N/ha.	620	631	612	603	78	77	75	71
Russet Burbank								
220 kg N/ha.	851	787	923	827	63	61	68	65
450 kg N/ha.	900	839	830	833	68	66	65	67
Furrow-irrigated plots								
Kennebeck								
38,000 plants/ha.	360	329	338	292	65	70	66	62
55,500 plants/ha.	335	349	317	332	76	78	77	75
Russet Burbank								
38,000 plants/ha.	360	347	347	360	64	65	61	63
55,500 plants/ha.	360	360	342	305	68	70	63	67

[a]Silt loam site.

[b]Quintal/hectare = cwt/acre x 1.12.

[c]D1 = 4.5 kg Di-Syston (actual) per ha., D2 = 9 kg Di-Syston/ha., D3 = 18 kg Di-Syston/ha., D4 = 36 kg Di-Syston/ha.

Table 46. SOIL ANALYSES, SPRINKLER-IRRIGATED DI-SYSTON PLOTS, OTHELLO STATION, 1974[a]

Treatment[b]	Norgold				Russet Burbank			
	May 16	June 26	July 23	Aug. 30	May 16	June 26	July 23	Aug. 30
	EC, mmho/cm							
N1D1	72.1	21.7	8.4	4.9	74.5	18.2	11.4	7.1
N1D2	78.1	13.3	10.6	7.4	66.9	14.8	16.6	7.3
N1D3	113.3	28.3	26.1	9.4	100.9	20.5	17.0	7.2
N1D4	91.7	12.9	7.8	4.3	76.5	13.1	10.4	7.2
N2D1	113.8	35.9	13.4	8.0	80.0	19.6	9.7	9.1
N2D2	70.7	20.3	14.3	6.7	102.6	17.7	16.8	6.2
N2D3	91.0	15.2	8.7	3.2	89.5	13.7	14.4	8.5
N2D4	84.7	19.2	12.4	4.5	66.0	15.8	12.6	5.1
	Cl, mg/l							
N1D1	8133	1601	13	10	9717	1277	10	11
N1D2	9070	390	43	25	7902	277	69	12
N1D3	9561	912	164	38	8981	213	77	28
N1D4	10736	71	68	43	8729	46	45	49
N2D1	8754	231	24	25	8764	151	81	4
N2D2	7483	323	27	15	9293	45	32	4
N2D3	6711	188	18	14	9594	270	96	70
N2D4	7405	325	74	134	6746	390	157	37

Table 46. (continued) SOIL ANALYSES, SPRINKLER-IRRIGATED DI-SYSTON PLOTS, OTHELLO STATION, 1974[a]

Treatment[b]	Norgold May 16	Norgold June 26	Norgold July 23	Norgold Aug. 30	Russet Burbank May 16	Russet Burbank June 26	Russet Burbank July 23	Russet Burbank Aug. 30
	Dissolved inorganic N, mg/l							
N1D1	5275	1588	27	16	4346	731	15	81
N1D2	16528	376	27	20	4807	157	64	11
N1D3	13407	856	255	55	10411	679	40	22
N1D4	6581	345	54	10	6697	378	55	20
N2D1	14419	2156	226	57	7099	1376	186	30
N2D2	6532	915	205	41	11620	913	405	27
N2D3	11065	947	43	14	8053	791	179	93
N2D4	9444	1442	389	43	5594	1134	475	31

[a]Silt loam site.

[b]N1 = 220 kg N/ha., N2 = 450 kg N/ha., D1 = 4.5 kg Di-Syston (actual)/ha., D2 = 9 kg Di-Syston/ha., D3 = 18 kg Di-Syston/ha., D4 = 36 kg Di-Syston/ha.

Table 47. SOIL ANALYSES, FURROW-IRRIGATED DI-SYSTON PLOTS, OTHELLO STATION, 1974[a]

Treatment[b]	Kennebeck June 26	Kennebeck July 23	Kennebeck Aug. 30	Russet Burbank June 26	Russet Burbank July 23	Russet Burbank Aug. 30
			EC, mmho/cm			
P1D1	25.9	17.8	8.8	30.2	21.0	16.3
P1D2	21.6	17.4	13.6	31.3	16.0	10.5
P1D3	26.3	20.8	9.5	29.0	21.3	8.2
P1D4	27.1	19.9	12.9	34.9	8.6	15.9
P2D1	16.2	20.7	10.8	21.2	39.4	15.3
P2D2	21.3	22.6	10.9	29.9	25.4	10.3
P2D3	13.6	8.7	5.9	30.9	11.8	8.3
P2D4	28.9	17.2	14.0	39.8	27.3	13.7
			Cl, mg/l			
P1D1	1579	503	48	1479	1606	858
P1D2	1027	709	123	2174	892	280
P1D3	1409	612	527	2170	1333	704
P1D4	1178	1038	197	1659	435	767
P2D1	481	1285	1904	829	2597	145
P2D2	936	1426	733	1972	258	751
P2D3	223	70	222	1685	597	123
P2D4	1516	845	907	2120	1864	612

Table 47. (continued) SOIL ANALYSES, FURROW-IRRIGATED DI-SYSTON PLOTS, OTHELLO STATION, 1974[a]

Treatment[b]	Kennebeck			Russet Burbank		
	June 26	July 23	Aug. 30	June 26	July 23	Aug. 30
	Dissolved inorganic N, mg/l					
P1D1	2568	712	69	2743	820	422
P1D2	2241	1295	88	2723	601	53
P1D3	2528	987	71	2532	983	47
P1D4	3035	1408	255	2170	346	137
P2D1	1414	771	100	1710	2864	337
P2D2	2128	865	109	3050	1488	498
P2D3	1492	373	58	2614	664	50
P2D4	2960	1016	460	4059	2098	370

[a]Silt loam site.

[b]P1 = 38,000 plants, ha., P2 = 55,500 plants/ha., D1 = 4.5 kg Di-Syston (actual)/ha., D2 = 9 kg Di-Syston/ha., D3 = 18 kg Di-Syston/ha., D4 = 36 kg Di-Syston/ha.

monthly intervals. Di-Syston analyses for these samples are given in Table 44, with salt (EC), chloride, and dissolved inorganic N levels for the same soil samples summarized in Tables 46 - 47. Although sampling variability was large, soil Di-Syston levels dropped more rapidly for the sprinkler-irrigated plots, and were negligibly small for the two lowest Di-Syston application rates (4.5 and 9 kg actual material/ha.) by late August. Substantial concentrations of Di-Syston remained in the fertilizer band for the entire season at the higher Di-Syston application rates, however, and even at the lower rates for many of the furrow-irrigated plots. No consistent effects of nitrogen fertilization rate (under sprinkler-irrigation) or plant population (under furrow-irrigation) on the rate of Di-Syston breakdown were evident from these data.

Levels of soluble fertilizer constituents such as chloride, dissolved inorganic N, and salts (reflected by the EC readings) generally decreased regularly throughout the growing season, with results for the highly-mobile chloride exhibiting the greatest deviations from this trend. No consistent trends with increasing N fertilization rate or increasing plant population were evident from the data.

Yield data for the 1974 Di-Syston experiments are given in Table 45. Increasing N fertilization rate generally increased total yield slightly, and increasing plant population consistently increased the percentage of U.S. No. 1 tubers. No definitive effects of increasing Di-Syston rate on tuber yields or quality were evident from the data. Yields were consistently and substantially higher for the sprinkler-irrigated plots, with the relative yields between varieties for a given experimental area remaining the same as for the 1974 petiole N experiment (discussed previously).

Runoff Samples, Othello Station, 1974

Furrow runoff samples for several of the 1974 experiments at the Othello Station were collected periodically throughout the season. Results of these analyses are given in Table 48. Additional runoff analyses for the 1973 season also are included in the table.

With the exception of one 1973 sampling, EC (dissolved salt) levels were low and similar to those of irrigation water supplied to the Othello Station. Again with the exception of one 1973 sample, dissolved chloride, N, and phosphorus levels were low. Some polyphosphate levels were unusually high, but these may have been experimental artifacts. Turbidity levels in runoff samples from this silt loam site generally were highest early in the season and declined to relatively low levels as furrows stabilized later in the season.

Table 48. PROPERTIES OF RUNOFF SAMPLES, FURROW-IRRIGATED PLOTS, OTHELLO STATION, 1974 and 1973[a]

Plot area	Date	Water on	Sampling	pH	EC, µmho/cm	Cl	N	Ortho-P	Poly-P	Turbidity, JTU
						all mg/liter				
Seed plots	7-10	9:00 AM[b]	1:30 PM	7.97	146	0.8	0	0.12	0.98	510
Seed plots	7-23	9:00 AM	5:15 PM	7.88	131	1.0	0	0.01	0	19
Seed plots	7-29	9:30 AM	3:25 PM	7.80	145	1.0	0	0.04	0.04	45
Di-Syston	7-10	9:00 AM	1:30 PM	7.73	134	1.1	0	0.02	0.04	160
Di-Syston	7-23	8:00 AM	5:15 PM	7.78	139	1.0	0.78	0.02	0.03	110
Di-Syston	7-29	9:30 AM	3:30 PM	7.90	131	1.3	0	0.01	0.78	75
Di-Syston	8-5	--	3:40 PM	7.76	128	0.5	0	0.01	0.04	58
Di-Syston	8-11	--	1:15 PM	7.92	125	0.4	0.15	0.01	0.02	28
Di-Syston	8-18	--	2:10 PM	7.77	133	0.8	0	0.01	0.39	43
Minimum tillage	7-10	8:00 AM	1:30 PM	8.06	148	0.9	0	0.07	0.10	170
Minimum tillage	7-29	9:00 AM	3:20 PM	7.97	141	0.9	0	0.13	16.6	110
Minimum tillage	8-5	--	3:30 PM	7.87	133	0.5	0	0.02	0.10	16
Minimum tillage	8-11	--	1:00 PM	7.86	142	0.4	0	0.05	0.01	2.5
Minimum tillage	8-18	--	2:00 PM	7.74	133	0.7	0	0.04	0.11	12
Variety trials	7-23	8:00 AM	5:30 PM	7.90	146	0.7	0	0.07	0.03	170
Variety trials	8-5	--	3:50 PM	7.67	133	0.8	0	0.01	0.11	16
Variety trails	8-11	--	1:20 PM	7.67	132	0.5	0	0.04	0.10	4.4
Variety trails	8-18	--	2:20 PM	7.86	135	0.5	0	0.01	0.10	3.7
1973 experiments	8-15	--	--	7.97	162	3.0	1.34	0.20	0.22	1.6
1973 experiments	8-23	--	--	7.87	228	10.4	2.55	0.31	0.06	120
1973 experiments	8-29	--	--	7.83	123	0.5	0	0.06	0.01	16

[a] Silt loam site.

[b] All plots at this location watered on a five-day rotation.

Minimum Tillage Experiment (Preliminary Sampling)

A final experiment of considerable environmental impact was sampled during the 1974 season. Dr. R. Kunkel of Washington State University has proposed the use of over-winter cover crops or second crops on potato lands to stabilize the soil against wind and water erosion and to "scavenge" residual N remaining in the soil profile following the potato cropping season. He has also proposed direct planting of potatoes into the chemically-killed stubble of this cover crop to aid in early-season erosion control and to minimize the number of tillage operations required on the land (with subsequent compaction and root restriction problems). Plots to demonstrate the feasibility of this approach were established on the Othello Station in the fall of 1973, and planted to potatoes in April of 1974. Fertilizer N had been applied to the plots at a rate of 340 kg/ha. at the same time as fall planting, to see whether fall fertilization of the potato crop could be employed. Results of the soil samplings are included in Table 49.

Average values for dissolved inorganic N in the top 60 cm of soil were low in all cases and never more than 2 times the maximum drinking water standard. This appears to reflect the combined effects of uptake of soluble N by the cover crop and leaching of nitrate from the surface soil layer during the over-winter period, with little conversion of additional N from the ammonium to the nitrate form because of cool soil temperatures during the early spring.

Values for soil solution N were markedly higher (averaging 8 to 18 times the maximum drinking water standard) for the 60- to 120-cm soil depth. These high levels of N 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 N 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 N concentrations occurred at between 60 and 150 cm of depth in all cases, with overlying and underlying soil exhibiting low N concentrations. Maximum dissolved-N values at all sites were of the same order of magnitude (95-272 mg/liter), suggesting that the movement of N resulted from 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 for the data is provided by the 1973-74 fall and winter rainfall data at Othello, as summarized in Table 49. Precipitation was approximately 50% higher at the site during this

Table 49. DISSOLVED INORGANIC N AND RAINFALL DATA, MINIMUM TILLAGE PLOTS, OTHELLO STATION, 1974[a]

Depth, cm	Dissolved inorganic N, mg/liter				Month	Precipitation, cm
	Wheat Plots		Ryegrass Plots			
	Average	Range	Average	Range		
0-30	22	4-45	14	5-35	Sept.	1.30
30-60	10	2-18	15	1-27	Oct.	3.15
60-90	82	25-183	128	24-166	Nov.	9.17
90-120	149	95-224	184	70-272	Dec.	7.26
120-150	58	5-106	43	4-102	Jan.	3.30
150-170	18	9-38	14	2-31	Feb.	2.21
					Mar.	0.00
					Total for period	26.39

[a]Furrow irrigation, silt loam site.

period than the long-term average, 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 0.17 cm of water per cm of depth at "field capacity", there was enough precipitation to move fertilizer nitrates to the 150-cm 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 rainfall values of Table 49 should be added the quantities of irrigation water applied for stand establishment and for 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 overwinter period, there appears to have been adequate water available at the Othello Station to produce the leaching recorded in Table 49.

The minimum tillage treatments used for this initial study not only failed to prevent N leaching following cropping to potatoes, but actually may have contributed additional N (from the heavy fall fertilization) to be moved through the soil during the wet over-winter period. The importance of minimum fertilization for cover establishment is thus demonstrated, as well as the importance of adding fall-applied N in predominantly 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 in retarding nitrate formation and subsequent leaching of N. By the time the soil bacterial population has multiplied again following fumigation, the average soil temperature may be low enough (less than approximately 10° C (50° F)) to inhibit conversion of ammonium N to the nitrate form. Fortunately, many grass cover crops are able to use either ammonium or nitrate N 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 N 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 required to maximize early fall growth of the cover crop while minimizing N leaching during the overwinter period. Use of only a small quality of "starter" N for the cover crop, with the main application of N 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 N management for such potato recrop systems.

SECTION VI

REFERENCES

1. American Public Health Association. 1965. Standard Methods for the Examination of Water and Wastewater, 12th Edition. American Public Health Association, New York. 874 p.

2. Bremner, J. M. 1965. Inorganic forms of nitrogen. In: C. A. Black, D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark, eds. Methods of Soil Analysis. American Society of Agronomy, Madison, Wisconsin. pp. 1179-1237.

3. Clapp, D. W. 1975. Di-Syston degradation in soil. Unpublished Ph.D. Dissertation, University of Idaho, Moscow. 52 p.

4. Cotlove, E. 1964. Determination of chloride in biological materials. In: David Glick, ed. Methods of Biochemical Analysis, Vol. XII. Interscience, New York. pp. 277-391.

5. Day, P. R. 1965. Particle fractionation and particle-size analysis. In: C. A. Black, D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark, eds. Methods of Soil Analysis. American Society of Agronomy, Madison, Wisconsin. pp. 545-567.

6. Grover, B. L. and R. E. Lamborn. 1970. Preparation of porous ceramic cups to be used for extraction of soil water having low solute concentrations. Soil Science Society of America, Proceedings 34: 706-708.

7. Jensen, M. C., J. E. Middleton, and W. O. Pruitt. 1961. Scheduling irrigation from pan evaporation. Circular 386, Washington Agricultural Experiment Station, Pullman. 14 p.

8. Murphy, J. and J. P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta 27: 31-36.

SECTION VII

PUBLICATIONS

1. Middleton, J. E., S. Roberts, B. L. McNeal, B. L. Carlile, D. W. James, and T. A. Cline. 1975. Irrigation and fertilizer management for efficient crop production on a sandy soil. Bulletin 811, Washington Agricultural Experiment Station, Pullman. 10 p.

2. McNeal, B. L., and R. Kunkel. 1973. Nitrate leaching following potato fertilization. In: Proceedings 12th Washington Potato Conference, February 6-8, 1973, in Moses Lake. pp. 103-109.

3. Shainberg, I., and B. L. McNeal. 1976. Evaluation of some theories of miscible displacement. Soil Science Society of America, Proceedings (submitted).

4. McNeal, B. L. 1975. Nitrogen, minimum tillage, and the Columbia Basin. In: Proceedings 14th Washington Potato Conference, February 4-6, 1975, in Moses Lake. pp. 75-79.

5. Diaz Zeballos, Cesar P. 1975. Soil testing versus petiole analysis as a predictor of potato yields in the Columbia Basin. Unpublished M.S. thesis, Washington State University, Pullman. 80 p.

6. Leifer, James T. 1976. Potato yield and quality at constant petiole NO_3-N levels. Unpublished M.S. thesis, Washington State University, Pullman. (Draft stage).

7. McNeal, B. L., R. Kunkel, and N. M. Ellsworth. 1973. Nitrate movement beneath irrigated potato fields. Agronomy Abstracts, 65th Annual Meeting. American Society of Agronomy, Madison, Wisconsin. p. 85.

8. Kunkel, R. B. L. McNeal, and C. B. Kresge. 1974. Effect of slow-release nitrogen compounds on the yield and quality of Russet Burbank potatoes in Washington. Agronomy Abstracts, 66th Annual Meeting. American Society of Agronomy, Madison, Wisconsin. p. 151.

9. McNeal, B. L., R. Kunkel, G. S. Campbell, and C. P. Diaz. 1974. Evaluation of some management alternatives to restrict nitrate leaching beneath irrigated potatoes. Proceedings Western Society of Soil Science, June 17-20, 1974, in Irvine, California. p. 14.

SECTION VIII

APPENDIX

Table No.		Page
A-1	Average EC Values, Soil Solutions, Block 21 Site, 1971	107
A-2	Average Dissolved Cl Values, Soil Solutions, Block 21 Site, 1971	108
A-3	Average Dissolved Inorganic N, Soil Solutions, Block 21 Site, 1971	109
A-4	EC Values, Soil Solutions, Sprinkler Irrigation, Block 21, 1970	110
A-5	Dissolved Cl Values, Soil Solutions, Sprinkler Irrigation, Block 21, 1970	111
A-6	Dissolved Inorganic N, Soil Solutions, Sprinkler Irrigation, Block 21, 1970	112
A-7	EC Values, Soil Solutions, Furrow Irrigation, Block 21, 1970	113
A-8	Dissolved Cl Values, Soil Solutions, Furrow Irrigation, Block 21, 1970	114
A-9	Dissolved Inorganic N, Soil Solutions, Furrow Irrigation, Block 21, 1970	115
A-10	Dissolved Inorganic N, Row-furrow Sets, Irrigation Rate and Sprinkler-irrigated Plots, Othello Station, Fall of 1972	116
A-11	EC Values, Row-furrow Sets, Furrow Irrigation Rate and Sprinkler-irrigated Plots, Othello Station, 1972	118
A-12	Dissolved Inorganic N, Selected Plots, Suspension Fertilizer and Slow-release N Experiments, Othello Station, 1972	120
A-13	Average Dissolved Inorganic N, Suspension Fertilizer Experiment, Othello Station, Fall of 1972	122
A-14	Average EC Values, Suspension Fertilizer Experiment, Othello Station, Fall of 1972	123

APPENDIX (continued)

Table No.		Page
A-15	Dissolved Inorganic N, Row-furrow Sets, Suspension Fertilizer and Fertilizer Factorial Experiments, Othello Station, Fall of 1972	124
A-16	Dissolved Inorganic N, 1971 Suspension Fertilizer Experiment, Othello Station, 1972	125
A-17	Average EC Values, 1971 Suspension Fertilizer Experiment, Othello Station, 1972	126
A-18	Average Yield, Selected Treatments, 1971 and 1972 Suspension Fertilizer Experiments, Othello Station	127
A-19	Average Dissolved Inorganic N, Fertilizer Factorial Experiment, Othello Station, Fall of 1972	128
A-20	Average Soil-test P and K Values, Fertilizer Factorial Experiment, Othello Station, 1965-1972	129
A-21	Average Soil-test P and K values with Depth, Fertilizer Factorial Experiment, Othello Station, Fall of 1972	130
A-22	Summarized Total Yield Data, Selected Treatments, Fertilizer Factorial Experiment, Othello Station, 1965-1972	131
A-23	Dissolved Inorganic N, Slow-release N Experiment, Othello Station, Fall of 1972	132
A-24	Summarized Yield Data, Selected Treatments, Slow-release N Experiment, Othello Station, 1972	133
A-25	Dissolved Inorganic N, and EC Data, 1971 Plant Population Experiment, Othello Station, Spring of 1972	134
A-26	Summarized Yield Data, Selected Treatments, 1971 and 1972 Plant Population Experiments, Othello Station	135
A-27	Dissolved Inorganic N, 0-30 cm Depth, Suspension Fertilizer Experiment, Moses Lake Area, 1973	136
A-28	Dissolved Inorganic N, 0-30 cm Depth, Suspension Fertilizer Experiment, Othello Area, 1973	137
A-29	Dissolved Inorganic N, 0-30 cm Depth, Slow-release N Experiment, Moses Lake Area, 1973	138
A-30	Dissolved Inorganic N, 0-30 cm Depth, Slow-release N Experiment, Othello Area, 1973	139
A-31	Dissolved Inorganic N, 0-30 cm Depth, Slow-release N Experiment, Othello Station, 1973	140

Table A-1. AVERAGE EC VALUES, SOIL SOLUTIONS, BLOCK 21 SITE, 1971 (mmho/cm)

Treatment	Depth, cm	5-5	5-26	6-11	6-18	6-25	7-1	7-8	7-15	7-29	8-12	8-26	9-9
Q1 (low-rate sprinkler)	60	--	.98	--	--	--	1.47	5.62	3.87	9.67	8.10	7.41	3.19
	90	1.16	1.01	1.97	1.03	1.09	1.15	1.39	1.43	3.22	2.39	6.50	6.32
	120	--	2.48	--	--	--	1.56	2.18	2.06	1.78	1.98	2.04	2.10
	180	--	--	2.42	--	--	2.01	2.97	2.96	3.02	2.00	2.17	2.20
	240	1.11	--	.95	--	--	--	2.22	1.87	2.38	5.45	2.37	2.53
	basalt	1.92	2.15	2.13	2.25	2.53	2.46	2.41	2.48	2.26	2.57	2.46	2.25
Q3 (high-rate sprinkler)	60	--	--	--	--	5.11	3.48	4.57	4.12	1.01	1.77	1.55	1.15
	90	1.21	1.09	1.44	1.55	1.47	2.06	3.00	3.50	3.06	1.83	2.48	3.24
	120	--	--	--	--	--	1.03	1.30	1.36	2.97	3.70	1.47	1.47
	180	--	--	1.21	--	2.20	.93	1.11	1.20	1.99	1.08	.93	.91
	240	3.41	3.01	2.59	--	2.13	2.25	2.35	1.82	1.80	2.59	1.76	1.32
	basalt	3.18	2.70	1.87	2.29	2.09	2.05	2.25	2.03	2.34	1.81	1.27	1.39
W1 (low-rate furrow)	60	--	--	--	1.39	--	1.87	--	.34	2.33	5.86	1.22	1.29
	90	1.27	1.27	3.07	3.25	4.05	6.53	6.24	5.33	2.46	2.44	.98	.72
	120	--	1.00	1.07	3.37	2.77	1.48	2.05	1.68	.89	.85	.78	.62
	180	2.34	1.19	1.21	1.03	1.41	3.94	4.08	1.98	1.60	2.75	.59	.78
	basalt	--	--	1.33	1.09	1.24	1.32	1.31	1.47	2.47	2.81	1.04	.78
W3 (high-rate furrow)	60	--	--	--	4.85	2.30	1.56	1.72	1.17	.78	.81	.56	.71
	90	1.11	1.82	1.72	1.97	2.62	2.34	1.01	1.00	.85	.90	.62	.70
	120	--	--	--	--	--	2.15	1.16	.97	.64	.64	.59	.61
	180	--	--	--	--	--	--	2.15	1.84	1.11	.71	.75	.66
	basalt	.83	.88	.87	1.86	1.10	1.04	1.37	1.37	1.04	.71	.64	.69

Cumulative average water application, cm:

	5-5	5-26	6-11	6-18	6-25	7-1	7-8	7-15	7-29	8-12	8-26	9-9
Q1	1.3	2.4	5.0	7.3	11.4	14.8	19.5	25.4	39.3	51.5	61.4	66.6
Q3	2.0	3.7	7.5	10.9	17.1	22.1	29.3	38.1	59.0	77.2	92.0	97.4
Rainfall	0.4	1.7	4.8	5.0	5.6	5.6	5.7	6.3	6.3	6.3	6.4	8.7

Table A-2. AVERAGE DISSOLVED Cl VALUES, SOIL SOLUTIONS, BLOCK 21 SITE, 1971 (mg/liter)

Treatment	Depth,cm	5-5	5-26	6-11	6-18	6-25	7-1	7-8	7-15	7-29	8-12	8-26	9-9
	60	---	73	---	---	---	95	439	438	765	460	510	118
Q1	90	43	50	181	70	77	111	122	134	375	282	332	684
(low-rate	120	---	257	---	---	---	122	276	142	94	269	120	136
sprinkler)	180	---	---	107	---	---	152	219	234	239	118	147	152
	240	53	---	55	---	---	---	49	44	163	555	127	153
		113	49	31	52	76	76	134	58	39	46	25	35
	60	---	---	---	---	576	265	335	328	67	50	50	61
Q3	90	58	83	56	224	63	101	175	272	287	46	148	737
(high-rate	120	---	---	---	---	229	62	73	65	214	247	78	69
sprinkler)	180	---	---	97	---	49	66	52	114	162	27	17	20
	240	103	97	102	---	88	86	77	87	100	191	43	42
		45	39	120	46	148	48	58	67	71	76	38	31
	60	---	---	---	34	---	95	---	18	112	124	46	45
W1	90	38	54	215	220	261	433	418	241	99	114	22	18
(low-rate	120	---	---	71	257	190	238	94	58	157	38	21	14
furrow)	180	125	44	57	52	102	339	415	126	66	88	17	15
		---	---	54	56	35	37	40	62	175	74	25	13
W3	60	---	---	---	319	110	71	88	39	27	25	11	16
(high-rate	90	35	193	157	132	183	126	45	29	21	24	7	9
furrow)	120	---	---	---	---	---	136	56	34	19	15	11	9
	180	---	---	---	---	---	---	192	124	43	17	15	10
		36	30	26	161	35	35	98	76	34	15	15	13

Table A-3. AVERAGE DISSOLVED INORGANIC N, SOIL SOLUTIONS, BLOCK 21 SITE, 1971 (mg/liter)

Treatment	Depth, cm	5-5	5-26	6-11	6-18	6-25	7-1	7-8	7-15	7-29	8-12	8-26	9-9
Q1 (low-rate sprinkler)	60	---	40	27	---	---	90	268	262	428	932	760	653
	90	16	23	71	18	28	58	28	16	127	56	417	549
	120	---	150	---	---	---	89	114	119	181	116	127	123
	180	---	35	40	---	---	125	204	226	143	54	121	129
	240	16	---	16	44	36	---	41	35	125	421	118	132
	basalt	22	23	24	27	28	29	25	38	148	54	75	31
Q3 (high-rate sprinkler)	60	---	---	---	14	393	345	371	346	117	105	35	21
	90	17	25	26	34	27	158	185	238	147	40	125	181
	120	---	39	37	33	36	23	11	16	242	313	60	63
	180	---	---	32	---	30	17	14	19	141	19	12	8
	240	102	101	99	---	123	81	69	56	22	151	39	20
	basalt	32	43	43	45	61	50	55	66	652	51	22	36
W1 (low-rate sprinkler)	60	---	---	---	22	---	144	580	15	159	2	46	5
	90	56	75	283	298	387	693	688	385	154	136	47	9
	120	---	31	107	303	175	162	181	132	128	51	19	3
	180	206	31	18	25	50	343	403	150	82	151	7	19
	basalt	---	---	22	27	28	37	42	63	167	105	15	2
W3 (high-rate furrow)	60	---	---	1330	514	310	118	146	81	48	25	2	1
	90	23	70	77	121	192	177	36	70	9	18	0	4
	120	---	---	---	---	---	174	71	49	9	7	2	1
	180	---	33	---	---	55	---	144	21	47	11	8	0
	basalt	9	7	5	98	10	18	56	43	32	8	1	1

Table A-4. EC VALUES, SOIL SOLUTIONS, SPRINKLER IRRIGATION, BLOCK 21, 1970

(mmho/cm)

Treatment	Depth, cm	4/20	5/28	6/4	6/8	6/11	6/17	6/19	6/22	7/3	7/21	8/5	8/20	9/4
Q1R1	30	-	-	-	-	-	-	-	-	-	-	-	-	-
(low-rate	60	-	-	3.90	-	7.47	-	-	-	10.2	7.58	4.00	-	2.83
sprinkler,	120	1.25	-	1.31	1.18	1.15	-	1.15	-	1.18	1.08	2.19	-	3.23
rep.1)	180	2.46	-	-	2.50	-	-	-	-	1.71	-	1.51	1.52	3.43
	basalt	1.46	-	1.41	1.33	1.35	-	1.49	-	1.40	1.48	1.35	1.19	1.26
Q1R2	30	-	-	-	-	-	-	-	-	-	-	-	-	-
(low-rate	60	3.19	-	-	1.94	-	-	-	-	1.40	-	1.65	1.63	2.01
sprinkler,	120	1.54	2.42	1.78	1.46	1.34	1.45	-	1.71	1.21	1.34	1.27	1.18	1.42
rep. 2)	180	4.79	4.44	3.58	2.55	2.77	2.89	-	2.71	2.44	2.48	2.06	1.62	1.65
	basalt	1.62	1.94	1.72	1.56	1.55	1.49	-	1.41	1.45	1.31	1.35	1.18	1.20
Q1R3	30	-	-	-	-	-	-	-	-	-	1.48	1.57	1.38	1.40
(low-rate	60	2.77	1.61	1.25	1.08	-	1.05	1.05	1.02	0.93	4.44	8.85	3.76	1.51
sprinkler,	120	1.07	1.33	1.08	1.08	0.96	1.00	0.93	1.11	1.01	1.25	1.42	1.27	1.70
rep. 3)	180	1.30	1.65	1.44	1.33	1.33	1.34	1.31	1.33	1.25	1.58	1.25	1.14	1.42
	basalt	2.22	2.18	1.90	1.77	1.74	1.74	1.68	1.71	1.65	1.18	1.64	1.43	1.18
Q3R1	30	11.51	-	-	1.84	-	-	-	-	0.67	-	-	-	-
(high-rate	60	2.22	5.58	6.26	5.45	-	-	6.46	7.41	6.93	2.87	1.31	1.18	1.48
sprinkler,	120	2.73	3.17	2.10	1.69	1.63	1.62	1.56	1.53	1.70	2.89	1.76	1.07	1.06
rep.1)	180	1.76	2.42	2.16	1.95	1.93	2.00	1.94	1.98	1.78	2.01	3.59	3.36	1.76
	basalt	2.30	2.22	1.96	1.78	1.72	1.77	1.78	1.78	1.74	1.66	1.65	1.52	2.42
Q3R2	30	5.25	13.33	1.45	1.54	-	1.78	15.07	10.24	2.02	2.22	2.02	2.07	2.36
(high-rate	60	-	-	-	-	-	-	1.81	-	4.65	2.08	1.77	1.14	-
sprinkler,	120	-	2.97	-	2.06	1.79	-	-	1.76	1.49	1.73	1.23	1.10	1.57
rep. 2)	180	-	2.69	1.78	1.34	1.29	-	1.26	1.26	1.14	3.19	4.15	1.03	0.93
	basalt	-	1.73	1.20	1.04	1.01	1.02	1.05	1.03	1.07	1.40	3.93	3.34	1.66
Q3R3	30	9.29	-	-	-	-	-	-	11.31	11.6	3.43	2.37	2.66	3.72
(high-rate	60	-	-	-	-	-	-	-	-	4.91	-	-	2.34	2.53
sprinkler,	120	1.01	-	1.64	1.25	1.22	1.29	1.25	1.32	1.78	6.34	5.20	2.39	1.47
rep.3)	180	1.39	-	2.77	2.22	1.90	2.06	1.94	1.90	1.70	4.20	5.05	1.79	1.53
	basalt	1.67	-	2.14	1.78	1.74	1.76	1.70	1.69	1.62	1.49	1.53	1.33	1.37

Table A-5. DISSOLVED Cl VALUES, SOIL SOLUTIONS, SPRINKLER IRRIGATION, BLOCK 21, 1970

(mg/liter)

Treatment	Depth, cm	4/20	5/28	6/11	6/22	7/3	7/21	8/5	8/20	9/4
Q1R1 (low-rate sprinkler, rep. 1)	30	-	-	-	-	-	-	-	-	-
	60	-	-	765	-	-	-	268	-	47
	120	22	-	24	-	25	19	173	33	263
	180	130	-	-	-	-	-	31	453	303
	basalt	17	-	24	-	21	28	5	0	10
Q1R2 (low-rate sprinkler, rep. 2)	30	21	-	-	-	-	-	-	-	-
	60	200	-	-	-	-	-	98	0	150
	120	61	34	27	100	19	28	17	0	7
	180	367	155	141	144	129	124	86	47	24
	basalt	33	34	24	25	19	7	0	0	4
Q1R3 (low-rate sprinkler, rep. 3)	30	-	-	-	-	-	15	21	24	18
	60	137	87	-	86	38	292	750	513	53
	120	24	17	-	19	26	78	116	77	98
	180	9	9	-	9	9	14	21	26	11
	basalt	102	39	-	27	24	11	12	11	50
Q3R1 (low-rate sprinkler, rep. 1)	30	1001	-	-	-	27	-	-	-	-
	60	128	364	-	649	551	140	23	20	29
	120	182	89	-	97	118	174	58	15	12
	180	17	18	-	19	34	104	251	225	57
	basalt	68	17	-	13	12	7	12	48	130
Q3R2 (low-rate sprinkler, rep. 2)	30	432	1109	-	870	28	4	4	18	47
	60	-	-	-	-	533	103	50	24	34
	120	-	54	-	-	69	78	12	12	17
	180	-	48	-	50	46	240	315	63	18
	basalt	-	25	-	22	24	43	312	200	32
Q3R3 (low-rate sprinkler, rep. 3)	30	872	-	-	832	818	295	68	12	9
	60	-	-	-	-	417	-	-	32	57
	120	37	-	-	126	152	426	233	58	16
	180	85	-	-	67	87	280	263	103	33
	basalt	22	-	-	15	11	32	41	65	58

Table A-6. DISSOLVED INORGANIC N, SOIL SOLUTIONS, SPRINKLER IRRIGATION, BLOCK 21, 1970

(mg/liter)

Treatment	Depth, cm	4/20	5/28	6/4	6/8	6/11	6/17	6/19	6/22	7/3	7/21	8/5	8/20	9/4
	30	-	-	-	-	-	-	-	-	-	-	-	-	-
Q1R1	60	-	-	357.6	-	765.3	-	-	-	-	-	268.0	-	47.0
(low-rate	120	21.6	-	40.4	21.7	24.5	-	19.3	-	25.0	19.0	173.0	33.0	263.0
sprinkler,	180	130.3	-	-	64.8	-	-	64.8	-	-	-	31.0	453.0	303.0
rep. 1)	basalt	16.8	-	0	15.2	24.2	-	26.8	-	21.0	28.0	5.0	0	10.0
	30	21.0	-	-	-	-	-	-	-	-	-	-	-	-
Q1R2	60	200.3	-	-	131.3	-	-	-	-	-	-	98.0	0	150.0
(low-rate	120	61.4	34.2	24.9	30.1	27.0	25.5	-	100.3	19.0	28.0	17.0	0	7.0
sprinkler,	180	367.1	155.5	149.3	109.2	140.9	149.3	-	143.6	129.0	124.0	86.0	47.0	24.0
rep.2)	basalt	33.1	34.2	34.2	32.5	24.4	31.1	-	24.8	19.0	7.0	0	0	4.0
	30	-	-	-	-	-	-	-	-	-	4.0	21.0	5.0	9.0
Q1R3	60	78.5	71.5	21.8	25.3	-	23.0	23.6	19.7	35.0	378.0	884.0	182.0	16.0
(low-rate	120	2.0	9.3	9.3	10.6	8.1	4.5	9.5	5.8	17.0	18.0	27.0	30.0	85.0
sprinkler,	180	8.4	15.6	6.2	5.3	8.8	0.5	10.5	0	13.0	4.0	18.0	16.0	10.0
rep.3)	basalt	132.8	46.7	6.2	25.8	28.0	18.6	9.5	13.3	15.0	12.0	9.0	10.0	18.0
	30	532.9	-	-	7.3	-	-	-	-	-	-	-	-	-
Q1R1	60	103.4	-	37.3	533.1	-	-	760.6	789.0	768.0	180.0	23.0	9.0	7.0
(high-rate	120	165.9	71.5	665.5	66.3	84.8	68.8	65.5	64.8	73.0	227.0	88.0	7.0	5.0
sprinkler,	180	5.9	6.2	65.3	5.0	2.4	5.9	3.6	4.8	9.0	47.0	238.0	261.0	6.0
rep.1)	basalt	74.8	9.3	9.3	1.7	5.7	2.5	13.2	6.8	3.0	5.0	2.0	15.0	98.0
	30	44.3	1490.0	3.1	1963.9	-	2245.0	1807.4	1148.5	7.0	4.0	0	0	5.0
Q3R2	60	-	-	-	-	-	-	74.4	-	300.0	-	-	19.0	-
(high-rate	120	-	-	-	71.9	71.3	-	-	65.0	52.0	16.0	0	5.0	0
sprinkler,	180	16.8	49.8	49.8	57.5	61.6	-	54.6	50.1	51.0	261.0	367.0	24.0	11.0
rep.2)	basalt	21.0	31.1	18.7	12.2	23.7	30.9	19.2	17.6	20.0	50.0	302.0	269.0	74.0
	30	904.2	-	-	-	-	-	-	-	1381.0	183.0	37.0	8.0	6.0
Q3R3	60	64.5	-	-	-	-	-	-	-	383.0	-	-	16.0	-
(high-rate	120	10.9	-	15.6	21.6	23.7	32.3	25.1	31.9	86.0	723.0	509.0	169.0	65.0
sprinkler,	180	55.2	-	46.7	42.8	41.6	37.2	52.6	43.7	28.0	442.0	495.0	67.0	23.0
rep.3)	basalt	6.7	-	6.2	0	4.1	5.2	0	2.5	6.0	7.0	6.0	9.0	41.0

Table A-7. EC VALUES, SOIL SOLUTIONS, FURROW IRRIGATION, BLOCK 21, 1970
(mmho/cm)

Treatment	Depth, cm	4/20	5/28	6/4	6/11	6/16	6/22	7/3	7/21	8/5	8/20	9/4
W3R1 (high-rate furrow, rep.1)	30	2.83	1.37	0.65	0.55	0.66	0.59	-	0.60	0.70	0.51	0.53
	60	4.44	9.49	0.72	0.65	0.67	0.51	-	0.56	0.56	0.49	0.53
	120	0.75	1.02	0.80	0.63	1.21	0.95	-	0.71	0.67	0.58	0.59
	180	1.01	1.22	0.98	0.78	-	0.72	0.76	0.68	0.67	0.60	0.62
	basalt	0.72	0.67	0.73	0.78	0.78	0.75	0.75	0.68	0.68	0.57	0.63
W3R2 (high-rate furrow, rep.2)	30	11.31	31.31	6.40	1.36	0.77	0.74	0.69	0.52	-	-	0.52
	60	0.81	4.34	0.22	3.03	1.06	0.95	0.60	0.55	0.54	-	0.50
	120	1.29	1.25	1.39	0.90	0.96	0.86	0.81	0.63	0.65	-	0.55
	180	2.08	0.86	0.70	0.65	0.58	0.59	0.61	0.57	0.60	-	0.53
	basalt	0.63	0.69	1.05	3.17	0.93	0.70	0.69	0.66	0.62	-	0.55
W3R3 (high-rate furrow, rep. 3)	30	2.40	-	-	1.55	-	-	3.29	2.36	1.22	-	0.73
	60	1.32	-	5.66	4.95	2.50	1.17	0.59	0.77	0.75	0.64	0.77
	120	2.10	-	-	4.36	3.31	1.37	0.65	0.73	0.74	0.69	0.77
	180	0.79	-	1.07	1.09	0.89	3.54	0.68	0.65	0.67	0.62	0.65
	basalt	0.91	-	1.01	1.03	0.89	0.80	0.70	0.69	0.71	0.60	0.63

Table A-8. DISSOLVED Cl VALUES, SOIL SOLUTIONS, FURROW IRRIGATION, BLOCK 21, 1970

(mg/liter)

Treatment	Depth, cm	4/20	5/28	6/4	6/11	6/22	7/3	7/21	8/5	9/4
W3R1 (high-rate furrow rep. 1)	30	-	44	11	-	16	-	17	23	17
	60	408	779	17	-	15	-	19	19	26
	120	21	32	19	-	14	-	24	22	18
	180	34	48	21	-	17	22	20	21	18
	basalt	23	19	17	-	21	20	20	20	19
W3R2 (high-rate furrow, rep. 2)	30	707	2705	369	-	18	19	17	-	16
	60	38	262	94	-	18	17	19	22	17
	120	41	35	84	-	16	17	18	18	16
	180	77	20	16	-	18	17	18	20	17
	basalt	20	-	53	-	19	19	20	19	17
W3R3 (high-rate furrow, rep. 3)	30	70	-	-	-	-	215	218	43	18
	60	33	-	396	-	54	17	18	15	22
	120	116	-	-	-	73	17	17	17	19
	180	22	-	22	-	232	17	15	18	17
	basalt	24	17	25	-	19	17	17	16	17

Table A-9. DISSOLVED INORGANIC N, SOIL SOLUTIONS, FURROW IRRIGATION, BLOCK 21, 1970

(mg/liter)

Treatment	Depth, cm	4/20	5/28	6/4	6/11	6/16	6/22	7/3	7/21	8/5	8/20	9/4
		34.5	46.7	24.9	0[a]	0	0	-	0	2	0	0
W3R1	30	255.0	-	34.2	12.1	20.4	10.7	-	0	0	0	3
(high-rate	60	22.7	-	21.8	17.1	90.0	52.6	-	0	0	0	2
furrow,	120	29.4	-	65.3	25.6	-	15.3	-	3	4	0	0
rep. 1)	180	7.6		6.2	21.5	14.3	11.6	-	0	4	0	2
	basalt											
		662.1	-	681.0	120.1	11.7	9.3	-	0	0	-	0
W3R2	30	38.4	255.0	208.4	377.7	88.0	82.2	14	0	3	-	0
(high-rate	60	88.8	-	84.0	35.3	38.8	30.0	21	0	1	-	0
furrow	120	64.5	0	15.6	12.0	0	0	0	7	0	-	2
rep. 2)	180	12.3	9.3	52.9	307.4	66.1	12.7	14	8	0	-	0
	basalt											
		89.4	-	-	1951.0	-	-	248	-	3	-	2
W3R3	30	7.0	-	550.0	506.5	215.7	47.6	5	12	0	2	0
(high-rate	60	84.8	-	-	28.3	298.0	98.9	0	4	0	0	0
furrow,	120	9.0	-	18.7	254.5	18.9	327.8	4	3	0	0	8
rep. 3)	180	11.5	-	3.1	23.8	9.9	0.4	0	0	0	0	3
	basalt											

[a]Below detectable limit.

Table A-10. DISSOLVED INORGANIC N, ROW-FURROW SETS, FURROW IRRIGATION RATE AND SPRINKLER-IRRIGATED PLOTS, OTHELLO STATION, FALL OF 1972

Treatment	Dissolved inorganic N, mg/l					Standard deviation, %				
	0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
Average of rows and furrows										
Head[a], Low N, High water	29	5	9	—	—	12	67	73	—	—
Head, High N, High water	88	4	3	—	—	100	125	159	—	—
Head, Low N, Low water	45	10	9	10	—	36	36	30	45	—
Head, High N, Low water	87	7	16	—	—	63	69	132	—	—
Tail, Low N, High water	95	10	9	29		50	75	102	41	
Tail, High N, High water	86	2	8	44	68	118	117	120	78	33
Tail, Low N, Low water	121	38	74	51	40	72	70	115	64	33
Tail, High N, Low water	159	94	184	157	74	72	48	14	28	27
Sprinkler[b], North end	137	14	63	94		129	63	93	94	
Sprinkler, Middle	56	35	20	30	9	66	139	72	130	24
Sprinkler, South end	47	14	11	88	39	43	116	87	112	39
Average of rows										
Head, Low N, High water	32	3	6	—	—	9	141	142	—	—
Head, High N, High water	56	7	6	—	—	30	40	94	—	—
Head, Low N, Low water	52	13	8	13	—	27	109	53	0	—
Head, High N, Low water	127	10	7	—	—	40	22	0	—	—
Tail, Low N, High water	108	5	3	24		67	141	142	30	
Tail, High N, High water	154	5	17	54	75	71	16	47	71	47
Tail, Low N, Low water	164	47	138	67	33	76	29	53	55	15
Tail, High N, Low water	102	66	179	134	78	47	56	14	20	6
Sprinkler, North end	48	11	113	136		12	47	6	53	
Sprinkler, Middle	71	67	16	53	10	76	86	59	96	37
Sprinkler, South end	38	19	14	7	33	48	142	81	141	15

Table A-10. (continued) DISSOLVED INORGANIC N, ROW-FURROW SETS, FURROW IRRIGATION RATE AND SPRINKLER-IRRIGATED PLOTS, OTHELLO STATION, FALL OF 1972

Treatment	Dissolved inorganic N, mg/l					Standard deviation, %				
	0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
Average of furrows										
Head, Low N, High water	27	7	12	—	—	3	11	35	—	—
Head, High N, High water	121	0	0	—	—	114	0	0	—	—
Head, Low N, Low water	37	7	9	—	—	50	0	0	—	—
Head, High N, Low water	48	5	24	—	—	13	141	130	—	—
Tail, Low N, High water	83	15	15	33	—	34	28	57	52	—
Tail, High N, High water	18	0	3	33	62	85	0	142	120	17
Tail, Low N, Low water	79	30	11	36	—	6	137	141	86	—
Tail, High N, Low water	217	121	189	180	71	71	34	19	29	47
Sprinkler, North end	227	17	13	—	—	109	75	17	—	—
Sprinkler, Middle	40	4	24	8	9	29	35	88	85	8
Sprinkler, South end	55	10	8	170	45	44	37	133	29	50

[a]Head = inflow portion of furrow-irrigated field (122 meter run), tail = outflow portion of furrow-irrigated field; low N and high N = 220 and 450 kg N/ha., banded at planting; low water and high water = wetting of alternate sides of a given crop row every 2 or 6 days, respectively (normal irrigation practice at the station involves an alternate-row interval of 2.5 days).

[b]Sprinkler plots were adjacent to the fertilizer factorial experiment, and received 450 kg N/ha., banded at planting, as a uniform fertilizer treatment.

Table A-11. EC VALUES, ROW-FURROW SETS, FURROW IRRIGATION RATE AND SPRINKLER-IRRIGATED PLOTS, OTHELLO STATION, FALL OF 1972

Treatment	Electrical conductivity, mmho/cm					Standard deviation, %				
	0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
Average of rows and furrows										
Head[a], Low N, High water	2.04	1.61	2.01	—	—	14	6	5	—	—
Head, High N, High water	3.24	1.77	1.73	—	—	34	8	2	—	—
Head, Low N, Low water	3.08	1.10	1.64	2.28	—	28	54	8	13	—
Head, High N, Low water	3.99	1.99	2.25	—	—	34	15	23	—	—
Tail, Low N, High water	3.69	2.81	2.43	2.37		28	48	5	12	
Tail, High N, High water	3.69	1.76	2.19	2.61	2.73	34	23	29	26	26
Tail, Low N, Low water	4.20	2.82	2.89	2.71	3.22	38	7	63	48	18
Tail, High N, Low water	5.51	3.95	4.68	4.69	3.99	31	40	21	16	13
Sprinkler[b], North end	3.70	2.38	2.71	3.06		7	6	29	32	
Sprinkler, Middle	4.12	3.33	2.37	3.78	2.05	18	60	19	100	7
Sprinkler, South end	3.00	1.79	1.41	2.87	2.66	14	20	9	49	21
Average of rows										
Head, Low N, High water	2.19	1.66	1.96	—	—	17	1	4	—	—
Head, High N, High water	2.55	1.67	1.72	—	—	7	7	2	—	—
Head, Low N, Low water	3.42	1.46	1.69	2.44	—	26	50	8	7	—
Head, High N, Low water	5.15	2.17	2.06	—	—	1	15	15	—	—
Tail, Low N, High water	4.19	3.65	2.50	2.15		35	44	4	4	
Tail, High N, High water	4.53	1.92	1.82	2.67	2.56	29	8	39	28	32
Tail, Low N, Low water	5.11	3.00	4.29	3.58	3.03	38	0	5	1	22
Tail, High N, Low water	3.81	3.09	4.34	4.13	4.25	32	36	16	1	13
Sprinkler, North end	3.72	2.47	3.39	3.51		1	6	48	25	
Sprinkler, Middle	4.65	4.36	2.29	5.72	2.17	11	63	25	92	2
Sprinkler, South end	3.07	1.77	1.40	1.69	2.44	23	33	16	5	14

Table A-11. (continued) EC VALUES, ROW-FURROW SETS, FURROW IRRIGATION RATE AND SPRINKLER-IRRIGATED PLOTS, OTHELLO STATION, FALL OF 1972

Treatment	Electrical conductivity, mmho/cm					Standard deviation, %				
	0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
Average of furrows										
Head, Low N, High water	1.89	1.56	2.07	—	—	4	8	4	—	—
Head, High N, High water	3.93	1.88	1.75	—	—	34	2	3	—	—
Head, Low N, Low water	2.75	0.74	1.59	—	—	36	4	9	—	—
Head, High N, Low water	2.82	1.80	2.44	—	—	4	8	31	—	—
Tail, Low N, High water	3.19	1.97	2.36	2.60		0	5	2	9	
Tail, High N, High water	2.85	1.60	2.57	2.55	$\overline{2.90}$	11	38	4	35	$\overline{28}$
Tail, Low N, Low water	3.30	2.64	1.50	1.85		25	3	94	78	
Tail, High N, Low water	7.21	4.81	5.03	5.25	$\overline{3.73}$	64	36	27	13	$\overline{13}$
Sprinkler, North end	3.67	2.28	2.04			13	0	3		
Sprinkler, Middle	3.59	2.30	2.44	$\overline{1.84}$	$\overline{1.94}$	13	12	21	$\overline{22}$	$\overline{5}$
Sprinkler, South end	2.94	1.81	1.43	4.05	2.89	4	5	1	14	28

[a]Head = inflow portion of furrow-irrigated field (122 meter run), tail = outflow portion of furrow-irrigated field; low N and high N = 220 and 450 kg N/ha., banded at planting; low water and high water = wetting of alternate sides of a given crop row every 2 or 6 days, respectively (normal irrigation practice at the station involves an alternate-row interval of 2.5 days).

[b]Sprinkler plots were adjacent to the fertilizer factorial experiment, and received 450 kg N/ha., banded at planting, as a uniform fertilizer treatment.

Table A-12. DISSOLVED INORGANIC N, SELECTED PLOTS, SUSPENSION FERTILIZER AND SLOW-RELEASE N EXPERIMENTS, OTHELLO STATION, 1972

Treatment[a]	Date	Dissolved inorganic N, mg/l					Standard deviation, %				
		0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
Suspension fertilizers											
670 kg/ha. banded, rep. 1	6/22	590	216	125	82	67	68	46	49	50	39
670 kg/ha. banded, rep. 1	8/3	123	78	132	108	103	137	146	57	30	20
670 kg/ha. banded, rep. 1	9/1	25	23	11	18	46	46	94	1	49	52
670 kg/ha. broadcast, rep. 5	6/22	139	136	315	154	101	142	129	43	46	32
670 kg/ha. broadcast, rep. 5	8/3	82	14	13	10	63	118	68	22	50	87
670 kg/ha. broadcast, rep. 5	9/1	39	68	114	154	115	28	132	140	102	96
670 kg/ha. banded, rep. 3	6/22	714	378	191	98	-	74	94	77	50	-
670 kg/ha. banded, rep. 3	8/3	398	380	153	141	53	74	15	60	66	67
670 kg/ha. banded, rep. 3	9/1	50	63	86	83	81	124	101	86	77	106
Slow-Release N											
NH_4NO_3											
340 kg/ha. + 170 kg/ha. UF	8/10	279	84	45	-	-	127	78	36	-	-
340 kg/ha. + 170 kg/ha. UF	8/29	17	10	45	-	-	26	43	58	-	-
340 kg/ha. + 170 kg/ha. SC 20	8/10	526	188	499	-	-	54	111	75	-	-

Table A-12. (continued) DISSOLVED INORGANIC N, SELECTED PLOTS, SUSPENSION FERTILIZER AND SLOW-RELEASE N EXPERIMENTS, OTHELLO STATION, 1972

Treatment	Date	Dissolved inorganic N, mg/l					Standard deviation, %				
		0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
NH_4NO_3 (continued)											
340 kg/ha. + 170 kg/ha. SC 20	8/29	142	15	21	-	-	147	46	83	-	-
340 kg/ha. + 170 kg/ha. SC 30	8/10	294	27	97	-	-	145	65	65	-	-
340 kg/ha. + 170 kg/ha. SC 30	8/29	51	13	35	-	-	37	28	43	-	-
500 kg/ha.	8/10	813	295	303	-	-	120	126	81	-	-
500 kg/ha.	8/29	81	65	83	-	-	76	118	76	-	-
$(NH_4)_2SO_4$											
340 kg/ha. + 170 kg/ha. UF	8/10	131	23	68	-	-	76	64	87	-	-
	8/29	17	8	17	-	-	45	36	51	-	-
340 kg/ha. + 170 kg/ha. SC 20	8/10	62	4	54	-	-	120	132	76	-	-
	8/29	51	20	37	-	-	62	63	110	-	-
340 kg/ha. + 170 kg/ha. SC 30	8/10	235	65	179	-	-	76	107	30	-	-
	8/29	27	15	66	-	-	70	52	72	-	-
500 kg/ha.	8/10	231	42	47	-	-	73	89	29	-	-
500 kg/ha.	8/29	47	46	54	-	-	68	130	96	-	-

[a]UF = urea-formaldehyde; SC 20 and SC 30 = sulfur-coated urea, 20% and 30% release of N in 7 days under standardized conditions.

Table A-13. AVERAGE DISSOLVED INORGANIC N, SUSPENSION FERTILIZER EXPERIMENT, OTHELLO STATION, FALL OF 1972.

Treatment	No. Reps. Sampled	Dissolved inorganic N, mg/l					Standard deviation, %				
		0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
One sample per plot											
110 kg/ha. broadcast	6	60	15	25	16	na[a]	29	55	113	40	na
450 kg/ha. broadcast	6	91	6	24	37	na	73	54	66	76	na
670 kg/ha. broadcast	6	117	60	40	47	na	123	181	117	53	na
110 kg/ha. banded	6	72	3	9	38	na	88	126	77	85	na
450 kg/ha. banded	6	82	8	13	22	—	63	84	97	114	—
670 kg/ha. banded	6	87	22	29	55	—	68	120	121	69	—
110 kg/ha. side-dressed	3	84	9	26	34	—	34	97	65	78	—
670 kg/ha. side-dressed	3	83	32	11	37	60	62	125	49	55	39
Paired within-plot samples											
110 kg/ha. broadcast	3	55	15	18	15	14	17	43	19	25	79
450 kg/ha. broadcast	3	62	9	24	63	—	16	75	61	2	—
670 kg/ha. broadcast	3	45	12	29	21	—	15	69	137	61	—
110 kg/ha. banded	3	63	6	7	32	—	39	58	58	74	—
450 kg/ha. banded	3	61	6	11	na	—	40	36	53	na	—
670 kg/ha. banded	3	157	44	54	—	—	39	103	63	—	—

[a] na = Sample volume not adequate for analysis.

Table A-14. AVERAGE EC VALUES, SUSPENSION FERTILIZER EXPERIMENT, OTHELLO STATION, FALL OF 1972

Treatment	No. Reps. Sampled	Electrical conductivity, mmho/cm					Standard deviation, %				
		0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
One sample per plot											
110 kg/ha. broadcast	6	3.18	1.72	2.64	3.51	na[a]	12	39	54	60	na
450 kg/ha. broadcast	6	3.63	2.19	2.68	3.38	na	49	18	35	28	na
670 kg/ha. broadcast	6	4.05	2.70	2.41	3.02	na	61	56	28	6	na
110 kg/ha. banded	6	2.85	1.61	1.96	2.85	na	43	26	8	34	na
450 kg/ha. banded	6	3.28	1.88	1.91	2.95	—	22	18	12	14	—
670 kg/ha. banded	6	3.17	2.14	2.49	3.02	—	36	30	31	18	—
110 kg/ha. side-dressed	3	3.44	1.67	2.02	2.99	—	34	52	26	30	—
670 kg/ha. side-dressed	3	3.12	2.64	1.95	2.76	5.98	22	42	1	12	10
Paired within-plot samples											
110 kg/ha. broadcast	3	3.26	1.39	3.13	3.51	7.25	6	11	7	7	21
450 kg/ha. broadcast	3	2.81	2.27	2.44	3.17	—	11	37	10	26	—
670 kg/ha. broadcast	3	2.98	2.14	2.27	2.87	—	11	28	28	15	—
110 kg/ha. banded	3	3.06	1.71	1.88	3.14	—	25	25	9	22	—
450 kg/ha. banded	3	2.79	1.92	2.00	na	—	26	21	10	na	—
670 kg/ha. banded	3	4.21	2.29	2.68	—	—	23	28	19	—	—

[a] na = sample volume not adequate for analysis.

124

Table A-15. DISSOLVED INORGANIC N, ROW-FURROW SETS, SUSPENSION FERTILIZER, AND FACTORIAL EXPERIMENTS, OTHELLO STATION, FALL OF 1972

Treatment[a]	Rep. No.	Dissolved inorganic N, mg/l 0-30 cm	30-60	60-120	120-180	180+ cm	Standard deviation, % 0-30 cm	30-60	60-120	120-130	180+ cm
Average of rows and furrows											
Suspension - 450 kg/ha. broadcast	1	93	2	10	7	—	21	200	115	87	—
Suspension - 670 kg/ha. broadcast	4	77	30	43	77	—	47	116	163	97	—
Suspension - 450 kg/ha. banded	3	84	13	23	na	—	62	25	71	na	—
Suspension - 670 kg/ha. banded	2	63	5	10	15	—	37	132	90	166	—
Factorial - $N_1P_4K_4$	1	243	92	55	21	9	114	57	68	20	16
Factorial - $N_4P_1K_1$	1	39	19	95	172	136	12	57	81	16	14
Average of rows											
Suspension - 450 kg/ha. broadcast	1	81	0	5	7	—	17	0	141	141	—
Suspension - 670 kg/ha. broadcast	4	53	46	75	58	—	35	107	136	132	—
Suspension - 450 kg/ha. banded	3	104	11	20	—	—	78	34	84	—	—
Suspension - 670 kg/ha. banded	2	68	9	10	31	—	56	92	141	104	—
Factorial - $N_1P_4K_4$	1	437	125	57	22	—	65	38	49	10	—
Factorial - $N_4P_1K_1$	1	42	22	156	160	132	12	6	35	17	19
Average of furrows											
Suspension - 450 kg/ha. broadcast	1	105	4	16	8	—	18	141	98	66	—
Suspension - 670 kg/ha. broadcast	4	101	14	11	97	—	36	79	47	100	—
Suspension - 450 kg/ha. banded	3	64	15	27	—	—	2	5	83	—	—
Suspension - 670 kg/ha. banded	2	59	1	10	1	—	13	141	67	140	—
Factorial - $N_1P_4K_4$	1	49	59	53	20	—	57	69	109	33	—
Factorial - $N_4P_1K_1$	1	36	15	35	184	140	8	113	10	17	14

[a]N = nitrogen, P = phosphorus, K = potassium; subscripts 1 and 4 indicate respectively approx. 0 or approx. 450 kg/ha. of the fertilizer nutrient (N, P_2O_5 or K_2O) applied annually for 1965-1967 and 1970-1971. 450 kg/ha. of N applied to all plots in 1972. Wheat grown to "mine" residual N from the plots in 1968 and 1969.

[b]na = Sample volume not adequate for analysis.

Table A-16. DISSOLVED INORGANIC N, 1971 SUSPENSION FERTILIZER EXPERIMENT, OTHELLO STATION, 1972

Treatment	No. Reps. Sampled	Dissolved inorganic N, mg/l 0-30 cm	30-60	60-120	120-180	180+ cm	Standard deviation, % 0-30 cm	30-60	60-120	120-180	180+ cm
<u>One sample per plot</u>											
<u>(Spring, 1972)</u>											
100 kg/ha. broadcast	6	105	49	23	24	—	25	33	35	60	—
450 kg/ha. broadcast	6	171	97	61	88	—	29	48	51	49	—
670 kg/ha. broadcast	6	231	166	97	65	—	24	53	36	51	—
110 kg/ha. banded	6	107	55	23	61	—	19	44	42	157	—
450 kg/ha. banded	6	180	110	69	73	—	31	56	79	65	—
670 kg/ha. banded	6	161	134	146	107	—	46	69	56	73	—
110 kg/ha. side-dressed	3	68	60	39	36	—	23	90	77	na[a]	—
670 kg/ha. side-dressed	3	263	153	142	100	—	24	74	75	112	—
<u>Paired within-plot samples</u>											
<u>(Spring, 1972)</u>											
110 kg/ha. broadcast	3	104	41	21	34	—	9	21	24	56	—
450 kg/ha. broadcast	3	213	130	85	97	—	14	40	32	43	—
670 kg/ha. broadcast	3	195	97	81	120	—	11	19	33	32	—
110 kg/ha. banded	3	111	62	22	21	—	27	58	10	27	—
450 kg/ha. banded	3	217	155	69	78	—	12	51	51	41	—
670 kg/ha. banded	3	207	199	162	94	—	25	51	61	41	—
<u>One sample per plot</u>											
<u>(Fall, 1972)</u>											
110 kg/ha. broadcast	6	10	14	27	33	—	25	101	63	76	—
670 kg/ha. broadcast	6	18	16	38	89	na	73	65	98	55	na
110 kg/ha. banded	6	15	18	34	42	na	43	55	62	58	na
670 kg/ha. banded	6	19	43	56	99	190	79	89	62	61	63

[a] na = Sample volume not adequate for analysis.

Table A-17. AVERAGE VALUES, 1971 SUSPENSION FERTILIZER EXPERIMENT, OTHELLO STATION, 1972

Treatment	No. Reps. Sampled	Electrical conductivity, mmho/cm 0-30 cm	30-60	60-120	120-180	180+ cm	Standard deviation, % 0-30 cm	30-60	60-120	120-180	180+ cm
One sample per plot											
(Spring, 1972)											
110 kg/ha. broadcast	6	3.19	2.18	2.60	2.64	—	21	42	16	13	—
450 kg/ha. broadcast	6	4.42	3.23	3.05	3.53	—	20	38	15	14	—
670 kg/ha. broadcast	6	5.10	4.56	3.38	3.65	—	20	38	12	31	—
110 kg/ha. banded	6	3.17	2.74	2.23	2.94	—	22	9	7	30	—
450 kg/ha. banded	6	4.01	2.48	2.58	3.16	—	30	39	29	17	—
670 kg/ha. banded	6	3.56	3.22	3.28	3.34	—	19	39	34	14	—
110 kg/ha. side-dressed	3	2.78	2.81	2.36	1.72	—	36	18	17	na[a]	—
670 kg/ha. side-dressed	3	4.76	3.26	3.78	3.36	—	18	24	32	42	—
Paired within-plot samples											
(Spring, 1972)											
110 kg/ha. broadcast	3	3.15	2.31	2.73	2.42	—	27	23	20	5	—
450 kg/ha. broadcast	3	5.16	3.62	3.22	3.62	—	5	15	4	12	—
670 kg/ha. broadcast	3	4.62	3.17	3.14	4.06	—	24	18	7	2	—
110 kg/ha. banded	3	3.31	2.77	2.24	2.55	—	5	7	9	6	—
450 kg/ha. banded	3	5.21	3.02	2.45	2.80	—	16	5	17	13	—
670 kg/ha. banded	3	3.85	3.96	3.56	3.30	—	20	22	35	8	—
One sample per plot											
(Fall, 1972)											
110 kg/ha. broadcast	6	2.09	1.58	2.22	2.03	—	10	24	16	2	—
670 kg/ha. broadcast	6	2.52	1.99	2.16	2.76	na	33	38	15	20	na
110 kg/ha. banded	6	2.42	1.91	2.04	2.65	na	29	35	19	47	na
670 kg/ha. banded	6	2.57	1.87	2.94	2.96	4.14	20	49	75	23	17

[a]na = Sample volume not adequate for analysis.

Table A-18. AVERAGE YIELD, SELECTED TREATMENTS, 1971 AND 1972 SUSPENSION FERTILIZER EXPERIMENTS, OTHELLO STATION

(quintal/hectare)[a]

Treatment	No. Reps. Sampled	1971		1972	
		Total	No. 1's	Total	No. 1's
110 kg/ha. broadcast	6	641	344	740	592
450 kg/ha. broadcast	6	874	503	878	704
670 kg/ha. broadcast	6	867	418	920	690
110 kg/ha. banded	6	681	402	796	676
450 kg/ha. banded	6	803	288	821	637
670 kg/ha. banded	6	768	253	790	590
110 kg/ha. side-dressed	3	650	383	737	570
670 kg/ha. side-dressed	3	879	321	851	582

[a]Quintal/hectare - cwt/acre x 1.12.

Table A-19. AVERAGE DISSOLVED INORGANIC N, FERTILIZER FACTORIAL EXPERIMENT, OTHELLO STATION, FALL OF 1972[a]

Treatment[b]	Dissolved inorganic N, mg/l					Standard deviation, %				
	0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
$N_1P_1K_1$	60	19	29	66	-	19	48	32	66	-
$N_4P_1K_1$	38	23	81	181	184	16	53	62	26	53
$N_1P_4K_1$	55	79	60	90	na[c]	104	184	63	116	na
$N_4P_4K_1$	47	25	136	142	-	30	68	89	86	-
$N_1P_1K_4$	79	23	25	49	na	51	24	16	39	na
$N_4P_1K_4$	48	60	134	181	88	91	170	89	54	32
$N_1P_4K_4$	127	58	30	43	na	80	66	80	96	na
$N_4P_4K_4$	59	49	144	195	-	31	77	104	61	-

[a]Average for replicates 1, 3, and 5.

[b]N = nitrogen, P = phosphorus, K = potassium; subscripts 1 and 4 indicate respectively approx. 0 or approx. 450 kg/ha. of the fertilizer nutrient (N, P_2O_5 or K_2O) applied annually for 1965-1967 and 1970–1971. 450 kg/ha. of N applied to all plots in 1972. Wheat grown to "mine" residual N from the plots in 1968 and 1969.

[c]na = Sample volume not adequate for analysis.

Table A-20. AVERAGE SOIL-TEST P AND K VALUES, FERTILIZER FACTORIAL EXPERIMENT, OTHELLO STATION 1965-1972[a]

(ppm, soil basis)

Treatment[b]	Phosphorus					Potassium				
	1965	1967	1968	1970	1972	1965	1967	1968	1970	1972
$N_1P_1K_1$	3.3	5.5	6.1	10.7	11.0	116	102	110	127	105
$N_4P_1K_1$	3.9	5.9	9.6	7.0	10.8	112	98	118	138	128
$N_1P_4K_1$	4.8	30+	31+	33.3	36.3	170	134	146	160	140
$N_4P_4K_1$	2.2	28+	31+	29.1	36+	106	96	114	125	105
$N_1P_1K_4$	3.8	5.6	7.9	11.0	13.8	234	194	282	248	248
$N_4P_1K_4$	2.4	5.4	6.6	8.1	10.2	114	150	216	168	180
$N_1P_4K_4$	1.7	31+	29+	31.7	36+	110	162	186	170	182
$N_4P_4K_4$	2.1	27.0	31+	29.2	36+	106	112	168	142	162

[a]Composited samples from the surface 20 cm of soil for replicates 1, 3, and 5, at the beginning of the season indicated.

[b]N = nitrogen, P = phosphorus, K = potassium; subscripts 1 and 4 indicate respectively approx. 0 or approx. 450 kg/ha. of the fertilizer nutrient (N, P_2O_5 or K_2O) applied annually for 1965-1967 and 1970-1971. 450 kg/ha. of N applied to all plots in 1972. Wheat grown to "mine" residual N from the plots in 1968 and 1969.

Table A-21. AVERAGE SOIL-TEST P AND K VALUES WITH DEPTH, FERTILIZER FACTORIAL EXPERIMENT, OTHELLO STATION, FALL OF 1972[a]

(ppm, soil basis)

Treatment[b]	Phosphorus					Potassium				
	0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
$N_1P_1K_1$	11.0	5.0	6.9	13.8	--	114	73	83	119	--
$N_4P_1K_1$	11.5	3.0	4.8	15.7	5.9	115	74	81	109	107
$N_1P_4K_1$	57.0	12.3	6.2	17.5	4.2	136	93	86	114	125
$N_4P_4K_1$	53.0	11.1	8.5	18.3	--	97	83	86	123	--
$N_1P_1K_4$	10.6	3.4	3.9	11.8	--	377	130	98	139	95
$N_4P_1K_4$	12.4	3.2	4.7	12.6	7.0	221	100	84	94	88
$N_1P_4K_4$	36.4	11.4	8.0	17.4	12.8	195	83	86	144	145
$N_4P_4K_4$	49.0	10.9	7.0	23.8	--	195	77	80	128	--

[a]Averages for replicates 1, 3, and 5.

[b]N = nitrogen, P = phosphorus, K = potassium; subscripts 1 and 4 indicate respectively approx. 0 or approx. 450 kg/ha. of the fertilizer nutrient (N, P_2O_5 or K_2O) applied annually for 1965-1967 and 1970-1971. 450 kg/ha. of N applied to all plots in 1972. Wheat grown to "mine" residual N from the plots in 1968 and 1969.

Table A-22. SUMMARIZED TOTAL YIELD DATA, SELECTED TREATMENTS, FERTILIZER FACTORIAL EXPERIMENT, OTHELLO STATION, 1965-1972[a]

Treatment[b]	Potatoes				Wheat		Potatoes		
	1965	1966	1967a[c]	1967b	1968	1969	1970	1971	1972
	(quintal/ha.)[d]				(hl/ha.)[e]		(quintal/ha.)		
$N_1P_1K_1$	423	167	104	206	30	7	236	375	416
$N_4P_1K_1$	608	422	270	427	77	17	412	492	520
$N_1P_4K_1$	545	396	271	438	53	5	293	572	582
$N_4P_4K_1$	709	430	252	377	74	20	491	540	493
$N_1P_1K_4$	577	196	136	278	37	7	197	520	645
$N_4P_1K_4$	641	512	287	476	89	17	411	519	539
$N_1P_4K_4$	600	296	214	308	36	6	243	573	651
$N_4P_4K_4$	785	707	327	452	77	14	601	650	640

[a]Averages for replicates 1, 3, and 5.

[b]N = nitrogen, P = phosphorus, K = potassium; subscripts 1 and 4 indicate respectively approx. 0 or approx. 450 kg/ha. of the fertilizer nutrient (N, P_2O_5 or K_2O) applied annually for 1965-1967 and 1970-1971. 450 kg/ha. of N applied to all plots in 1972. Wheat grown to "mine" residual N from the plots in 1968 and 1969.

[c]1967 a = non-fumigated, 1967 b = fumigated.

[d]Quintal/hectare = cwt/acre x 1.12.

[e]Hectoliter/hectare = bu/acre x 0.87.

Table A-23. DISSOLVED INORGANIC N, SLOW-RELEASE N EXPERIMENT, OTHELLO STATION, FALL OF 1972[a]

Treatment[b]	Dissolved inorganic N, mg/l					Standard deviation, %				
	0-30 cm	30-60	60-120	120-180	180+ cm	0-30 cm	30-60	60-120	120-180	180+ cm
NH_4NO_3										
340 kg/ha.	71	7	3	na[c]	-	32	150	115	na	-
340 kg/ha. + 170 kg/ha. UF	77	86	84	164	-	39	142	100	92	-
340 kg/ha. + 170 kg/ha. SC 20	178	2	4	129	na	76	133	100	82	na
340 kg/ha. + 170 kg/ha. SC 30	68	5	11	53	na	30	125	61	117	na
500 kg/ha.	74	8	17	na	-	69	143	34	na	-
$(NH_4)_2SO_4$										
340 kg/ha.	101	5	5	14	-	46	173	114	47	-
340 kg/ha. + 170 kg/ha. UF	66	10	8	52	24	44	116	119	119	93
340 kg/ha. + 170 kg/ha. SC 20	43	24	11	na	na	36	131	14	na	na
340 kg/ha. + 170 kg/ha. SC 30	105	9	39	48	na	60	93	45	109	na
500 kg/ha.	110	26	76	na	-	25	67	64	na	-
Urea										
340 kg/ha.	95	13	28	73	na	57	129	173	90	na
340 kg/ha. + 170 kg/ha. UF	112	6	25	na	na	47	142	78	na	na
340 kg/ha. + 170 kg/ha. SC 20	118	9	8	51	-	87	99	54	49	-
340 kg/ha. + 170 kg/ha. SC 30	201	39	7	101	na	91	49	103	42	na
500 kg/ha.	114	4	8	na	-	41	35	152	na	-
SC 100										
340 kg/ha.	63	14	7	38	na	12	71	75	104	na
340 kg/ha. + 170 kg/ha. UF	191	7	13	58	-	56	172	66	28	-
340 kg/ha. + 170 kg/ha. SC 20	279	20	26	79	na	86	111	109	73	na
340 kg/ha. + 170 kg/ha. SC 30	127	16	4	83	na	7	41	132	124	na
500 kg/ha.	61	13	21	39	na	28	89	33	73	na
SC 20										
500 kg/ha.	103	9	4	32	-	89	74	87	89	-
SC 30										
500 kg/ha.	203	5	49	40	-	103	173	95	13	-

[a] For replicates 1, 3, and 5.

[b] UF = urea-formaldehyde; SC 20 and SC 30 = sulfur-coated urea, 20% and 30% release of N in 7 days under standardized conditions.

[c] na = Sample volume not adequate for analysis.

Table A-24. SUMMARIZED YIELD DATA, SELECTED TREATMENTS, SLOW-RELEASE N EXPERIMENT, OTHELLO STATION, 1972[a]
(quintal/hectare)[c]

Treatment[b]	Total	No. 1's
NH_4NO_3		
340 kg/ha.	741	601
340 kg/ha. + 170 kg/ha. UF	764	579
340 kg/ha. + 170 kg/ha. SC 20	860	617
340 kg/ha. + 170 kg/ha. SC 30	756	547
500 kg/ha.	782	584
$(NH_4)_2SO_4$		
340 kg/ha.	793	613
340 kg/ha. + 170 kg/ha. UF	702	491
340 kg/ha. + 170 kg/ha. SC 20	654	441
340 kg/ha. + 170 kg/ha. SC 30	721	589
500 kg/ha.	740	493
Urea		
340 kg/ha.	731	584
340 kg/ha. + 170 kg/ha. UF	749	560
340 kg/ha. + 170 kg/ha. SC 20	663	466
340 kg/ha. + 170 kg/ha. SC 30	744	532
500 kg/ha.	716	468

Treatment	Total	No. 1's
SC 100		
340 kg/ha.	712	596
340 kg/ha. + 170 kg/ha. UF	720	551
340 kg/ha. + 170 kg/ha. SC 20	741	548
340 kg/ha. + 170 kg/ha. SC 30	709	580
500 kg/ha.	689	484
SC 20		
500 kg/ha.	792	575
SC 30		
500 kg/ha.	844	626

[a] Average for replicates 1, 3, and 5.

[b] UF = urea-formaldehyde; SC 20 and SC 30 = sulfur-coated urea, 20% and 30% release of N in 7 days under standardized conditions.

[c] Quintal/ha. = cwt/acre x 1.12.

Table A-25. DISSOLVED INORGANIC N AND EC DATA, 1971 PLANT POPULATION EXPERIMENT, OTHELLO STATION, SPRING OF 1972

Treatment	No. Reps. Sampled	Dissolved inorganic N, mg/l 0-30 cm	30-60	60-120	120-180	180+ cm	Electrical conductivity, mmho/cm 0-30 cm	30-60	60-120	120-180	180+ cm
Low population, low N[a]	6	119	101	30	43	na[b]	3.32	3.10	2.62	3.00	na
Low population, high N	6	135	74	32	32	-	3.55	2.94	2.46	2.59	-
High population, low N	6	129	80	20	34	na	3.56	3.11	2.31	2.55	na
High population, high N	6	92	60	20	21	-	2.59	2.74	2.15	2.78	-
		Standard deviation, %					Standard deviation, %				
Low population, low N	6	27	99	95	152	na	15	42	24	28	na
Low population, high N	6	64	88	54	58	-	34	46	14	13	-
High population, low N	6	25	49	37	64	na	12	24	9	19	na
High population, high N	6	38	56	33	83	-	10	18	8	26	-

[a] Low population and high population =44000 and 73000 plants/ha., respectively; low N = 110 and 187 kg N/ha. for the low and high plant populations, respectively; high N = 450 and 752 kg N/ha. for the low and high plant populations, respectively.

[b] na = Sample volume not adequate for analysis.

Table A-26. SUMMARIZED YIELD DATA, SELECTED TREATMENTS, 1971 AND 1972 PLANT POPULATION EXPERIMENTS, OTHELLO STATION

(quintal/hectare)[a]

Treatment[b]	No. Reps. Sampled	1971 Total	1971 No. 1's	1972 Total	1972 No. 1's
Low population, low N	6	573	291	681	547
Low population, high N	6	708	309	782	598
High population, low N	6	749	454	693	566
High population, high N	6	790	278	825	595

[a]Quintal/hectare = cwt/acre x 1.12.

[b]Low population and high population = 44000 and 73000 plant/ha., respectively; low N = 110 and 187 kg N/ha. for the low and high plant populations, respectively; high N = 450 and 752 kg N/ha. for the low and high plant populations, respectively.

Table A-27. DISSOLVED INORGANIC N, 0-30 CM DEPTH, SUSPENSION FERTILIZER EXPERIMENT, MOSES LAKE AREA, 1973[a]

Treatment[b]	August 1								August 14							
	Dissolved N, mg/l				Std. deviation, %				Dissolved N, mg/l				Std. deviation, %			
	R	F	1/2	Reps	R	F	1/2	Reps	R	F	1/2	Reps	R	F	1/2	Reps
F1BaL	79	5	16	33	39	180	25	119	8	79	26	38	50	10	35	99
F4BaL	213	19	10	80	86	37	90	128	15	238	16	90	53	42	50	143
F1BaD	101	3	64	56	146	100	123	99	11	165	31	69	46	104	61	110
F4BaD	88	28	10	42	91	104	60	133	10	139	19	56	90	97	53	120
F1BrL	29	10	6	15	83	50	83	86	5	70	12	29	40	21	33	122
F4BrL	128	6	48	61	56	117	113	105	77	69	73	73	144	128	106	75
F1BrD	59	6	13	26	110	100	100	139	10	28	10	16	80	25	70	73
F4BrD	117	7	17	47	97	100	65	108	3	50	33	29	100	52	149	116

[a]Rill irrigation, sandy site, 3 replicates sampled.

[b]F1 and F4 = 110 and 450 kg/ha. of N, P_2O_5 and K_2O respectively. Ba = banded, Br = broadcast. L = suspension fertilizer, D= dry fertilizer. R = crop row, F = irrigation furrow, 1/2 = 1/2 way between row and furrow, Reps = average values for the three replicates. Planted May 1-2, harvested October 4-5. Russet Burbank potatoes.

Table A-28. DISSOLVED INORGANIC N, 0-30 CM DEPTH, SUSPENSION FERTILIZER EXPERIMENT, OTHELLO AREA, 1973[a]

Treatment[b]	Dissolved N, mg/l R	F	1/2	Reps	Std. deviation, % R	F	1/2	Reps	Dissolved N, mg/l R	F	1/2	Reps	Std. deviation, % R	F	1/2	Reps
					July 17								August 22			
F1BaL	13	5	10	9	39	120	30	57	14	15	15	15	64	27	67	32
F4BaL	150	141	21	104	152	157	114	62	81	39	73	65	135	113	127	32
F1BaD	13	11	16	13	54	18	63	47	17	14	14	15	94	71	57	42
F4BaD	70	13	21	34	114	54	38	69	49	32	32	38	98	47	38	30
F1BrL	107	15	30	51	144	67	70	69	23	16	23	21	65	88	100	29
F4BrL	185	43	54	94	82	65	56	77	37	59	35	44	105	80	80	39
F1BrD	8	5	15	9	13	80	27	63	13	6	7	9	62	83	57	60
F4BrD	18	14	18	16	67	86	61	41	30	21	14	22	27	43	43	48
					August 10								August 30 & 31			
F1BaL	8	4	11	8	50	100	82	84	10	9	6	8	90	122	33	98
F4BaL	45	142	42	76	80	147	95	48	87	67	65	73	145	161	165	67
F1BaD	8	9	9	8	88	78	111	86	7	2	6	5	14	100	117	104
F4BaD	17	40	26	28	53	100	58	45	33	29	12	25	24	45	133	56
F1BrL	21	26	15	21	81	85	93	65	21	10	13	15	110	90	31	60
F4BrL	39	53	20	37	80	121	80	51	33	48	20	34	100	123	85	58
F1BrD	7	20	8	12	29	50	100	76	11	3	10	8	64	167	20	82
F4BrD	11	17	15	14	55	24	40	39	16	12	8	12	88	75	88	79

[a]Solid-set sprinkler system, silt loam site, 3 replicates sampled.

[b]F1 and F4 = 110 and 450 kg/ha. N, P_2O_5, and K_2O respectively. Ba = banded, Br = broadcast. L = suspension fertilizer, D = dry fertilizer. R = crop row, F = irrigation furrow, 1/2 = 1/2 way between row and furrow. Reps = average values for the three replicates. Fumigation with Telone C at 230 liters/ha. (25 gal/acre). Planted April 20-24, harvested October 17-19. Russet Burbank potatoes.

Table A-29. DISSOLVED INORGANIC N, 0-30 CM DEPTH, SLOW-RELEASE N EXPERIMENT, MOSES LAKE AREA, 1973[a]

	Dissolved N, mg/l				Std. deviation, %			
Treatment[b]	R	F	1/2	Reps	R	F	1/2	Reps
				August 1				
170 kg/ha. NH_4NO_3	61	7	7	25	82	29	43	106
170 kg/ha. Urea	71	8	8	29	132	38	88	90
170 kg/ha. SCU 100	38	4	6	16	55	25	133	123
170 kg/ha. SCU 25	40	10	10	20	43	40	70	89
390 kg/ha. NH_4NO_3	118	12	16	49	74	42	106	115
390 kg/ha. Urea	138	18	36	64	48	28	22	95
390 kg/ha. SCU 100	31	10	10	17	61	80	90	88
390 kg/ha. SCU 25	34	26	12	24	44	96	50	74
				August 14				
170 kg/ha. NH_4NO_3	14	138	36	63	57	88	58	85
170 kg/ha. Urea	16	71	20	36	56	69	65	72
170 kg/ha. SCU 100	10	87	16	38	90	82	69	110
170 kg/ha. SCU 25	9	60	35	34	100	72	109	95
390 kg/ha. NH_4NO_3	20	328	53	134	80	49	28	124
390 kg/ha. Urea	11	269	44	108	27	6	57	131
390 kg/ha. SCU 100	13	93	34	47	62	80	91	88
390 kg/ha. SCU 25	20	128	27	58	30	114	15	91

[a]Furrow irrigation, sandy site, 3 replicates sampled.

[b]SCU 100 and SCU 25 = sulfur-coated ureas releasing 100% and 25% of their N, respectively, during the standard 7-day leaching test. R = crop row, F = irrigation furrow, 1/2 = 1/2 way between row and furrow, Reps = average values for the three replicates. Planted May 1, harvested October 8. Russet Burbank potatoes.

Table A-30. DISSOLVED INORGANIC N, 0-30 CM DEPTH, SLOW-RELEASE N EXPERIMENT, OTHELLO AREA, 1973[a]

Treatment[b]	Dissolved N, mg/l				Std. deviation, %				Dissolved N, mg/l				Std. deviation, %			
	R	F	1/2	Reps	R	F	1/2	Reps	R	F	1/2	Reps	R	F	1/2	Reps
	July 17								August 22							
170 kg/ha. NH_4NO_3	16	19	14	16	81	11	29	40	10	19	12	14	140	53	67	64
170 kg/ha. Urea	22	15	15	17	77	33	100	47	16	7	10	11	88	100	20	88
170 kg/ha. SCU100	25	17	23	22	16	12	9	23	26	18	13	19	73	61	54	51
170 kg/ha. SCU25	38	6	22	22	24	133	55	82	32	15	20	22	47	33	75	66
500 kg/ha. NH_4NO_3	202	20	40	87	18	50	20	115	27	36	22	28	82	53	73	35
500 kg/ha. Urea	253	6	29	96	63	150	31	135	23	34	31	30	35	29	39	29
500 kg/ha. SCU100	143	14	21	60	52	43	33	120	51	25	28	34	63	12	11	40
500 kg/ha. SCU25	55	16	29	33	51	69	31	75	99	34	36	56	34	32	56	67
	August 1								August 30 & 31							
170 kg/ha. NH_4NO_3	17	16	23	19	18	63	57	34	15	23	17	18	60	26	59	38
170 kg/ha. Urea	30	17	42	30	73	77	95	38	15	15	14	15	33	33	29	25
170 kg/ha. SCU100	45	25	29	33	62	40	52	38	26	18	24	23	46	33	25	35
170 kg/ha. SCU25	31	21	17	23	45	67	65	39	30	20	20	23	60	30	25	35
500 kg/ha. NH_4NO_3	54	65	31	50	50	51	42	52	42	31	34	35	26	13	21	16
500 kg/ha. Urea	129	54	40	74	88	74	83	65	27	46	22	32	19	17	9	41
500 kg/ha. SCU100	110	39	30	60	20	23	30	74	59	49	33	47	41	51	21	41
500 kg/ha. SCU25	93	23	23	46	134	74	48	81	52	36	20	36	67	81	35	43

[a]Solid-set sprinkler system, silt loam site, 3 replicates sampled.

[b]SCU 100 and SCU 25 = sulfur-coated urea releasing 100% and 25% of their N, respectively, during the standard 7-day leaching test. R = crop row, F = irrigation furrow, 1/2 = 1/2 way between row and furrow, Reps = average values for the three replicates. Planted April 19, harvested October 17. Russet Burbank potatoes.

Table A-31. DISSOLVED INORGANIC N, 0-30 CM DEPTH, SLOW-RELEASE N EXPERIMENT, OTHELLO STATION, 1973[a]

Treatment[b]	Dissolved N, mg/l				Std. deviation, %				Dissolved N, mg/l				Std. deviation, %			
	R	F	1/2	Reps	R	F	1/2	Reps	R	F	1/2	Reps	R	F	1/2	Reps
	July 24								August 23							
170 kg/ha. NH_4NO_3	98	21	61	60	125	33	105	48	29	20	22	24	35	25	41	24
170 kg/ha. Urea	54	30	55	46	72	27	93	44	28	28	34	30	21	7	21	17
170 kg/ha. SCU 100	73	13	20	35	96	39	30	77	51	11	17	26	37	46	35	80
170 kg/ha. SCU 25	45	19	35	33	29	21	26	39	38	20	23	27	55	30	39	36
500 kg/ha. NH_4NO_3	1387	40	429	619	108	73	111	95	289	35	88	137	94	9	66	70
500 kg/ha. Urea	708	54	187	317	65	46	94	102	232	33	33	99	132	52	46	80
500 kg/ha. SCU 100	924	48	394	455	74	38	87	95	320	66	129	166	129	35	138	59
500 kg/ha. SCU 25	251	15	54	107	123	53	98	99	219	38	33	97	135	13	33	72
	August 10								August 30 & 31							
170 kg/ha. NH_4NO_3	18	31	22	23	33	55	73	43	50	30	19	33	52	43	58	50
170 kg/ha. Urea	19	27	23	23	47	7	48	33	40	25	26	30	45	36	42	27
170 kg/ha. SCU 100	12	28	18	19	42	89	44	47	30	35	16	27	27	40	75	39
170 kg/ha. SCU 25	19	35	32	29	21	31	41	42	52	34	26	37	37	27	31	36
500 kg/ha. NH_4NO_3	36	394	150	194	31	61	65	97	347	35	107	163	110	9	130	85
500 kg/ha. Urea	32	436	110	193	72	62	83	109	330	54	43	142	97	15	35	92
500 kg/ha. SCU 100	36	360	191	196	39	38	79	95	494	34	172	234	121	32	149	101
500 kg/ha. SCU 25	26	197	33	85	23	129	42	70	230	52	36	106	100	48	28	82

[a] Furrow irrigation, silt loam site; 3 replicates sampled.

[b] SCU 100 and SCU 25 = sulfur-coated ureas releasing 100% and 25% of their N, respectively, during the standard 7-day leaching test. R = crop row, F = irrigation furrow, 1/2 = 1/2 way between row and furrow, Reps = average values for the three replicates. Planted May 1, harvested October 30 and November 2, Russet Burbank potatoes.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-76-158	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Nitrogen and Irrigation Management to Reduce Return-flow Pollution in the Columbia Basin		5. REPORT DATE September 1976 (Issuing Date) 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Brian L. McNeal Bobby L. Carlile		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Agronomy and Soils Washington State University Pullman, Washington 99163		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. S-801187
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Research and Development Robert S. Kerr Environmental Research Laboratory Ada, Oklahoma 74820		13. TYPE OF REPORT AND PERIOD COVERED Final-May 1971 to October 1974 14. SPONSORING AGENCY CODE EPA-ORD

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Cooperative field studies have evaluated dissolved-N levels and leaching, and corresponding crop yields, for potato production practices in the Columbia Basin area of Washington. High dissolved-N levels (with resultant high potential for return-flow pollution) were found throughout the growing season in well-managed potato fields, with levels decreased by decreasing fertilization rate, use of slow-release N fertilizers or nitrification inhibitors, or sprinkler application of N fertilizers.

Careful water management with solid-set sprinkler proved capable of maintaining dissolved-N within the root zone of subsequent crops by season's end, even on very sandy sites. Alternate-furrow irrigation proved effective in "trapping" banded fertilizer N within the plant root zone on heavier-textured furrow-irrigated soils. Periodic "mining" of residual N by other crops in the rotation would still be necessary to prevent eventual return-flow contamination, however.

Site-to-site sampling variability necessitates the use of composited soil samples, rather than fixed-position soil solution extraction cups, for adequate monitoring of N in soils of this area. Neither dissolved soil N nor plant petiole nitrate-N proved to be reliable predictors of crop N needs under the conditions tested.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water pollution, nitrogen, irrigation, ground water, soil water, potatoes	soil water samplers, extraction cups, petiole analyses, nitrates, Columbia River Basin	02-C

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 151
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1976-657-695/6116 Region No. 5-11