NITROGEN IN SURFACE RUNOFF RESULTING FROM ADDITION OF FERTILIZERS TO IRRIGATION WATER[1]

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Environmental pollution has become one of the most important of mankind's problems. Society, through its concern for the environment, is beginning to formulate policies, laws and institutions to deal with this problem. One area of concern is the possibility that fertilizers applied to land may contribute to the deterioration of the environment.

While much has been written about the potential for water pollution by the continually increasing use of inorganic fertilizer materials on agricultural land, there is very little factual information available on the actual contribution of fertilizers to water quality deterioration. There is also very little published information on the effects of various management practices on the quality of runoff from agricultural land in irrigated areas.

The usual approach to the problem has been to assign certain inputs of nutrients to identifiable industries and municipal sewage plants and to charge the rest by difference to agricultural runoff (Viets, 1970). Agricultural runoff, in this case, includes animal wastes flushed off feedlots, fields and pastures; eroding soil; washout of nutrients from dead vegetation; leaching from rural septic tanks; and, of course, fertilizer materials either in solution or adsorbed onto eroding sediment.

Information relative to the behavior of nitrogen in soil including its origin, distribution, loss from the soil profile, and the many biological reactions that occur has been published (Bartholomew and Clark, 1960). The general area of eutrophication has been reviewed and sources of nutrients discussed (Stewart and Rohlich, 1967). Results of work in the state of Washington (Sylvester and Seabloom, 1963) indicated that irrigation return flow was an important influence on the quality of water in the Yakima River.

Water quality is important for the future of the Boise Valley in Southwestern Idaho, not only from the standpoint of agriculture but also for the rapidly growing population of this area. Prior to the initiation of the study reported herein there has been no information concerning the contributions of agricultural fertilizer or management practices on the quality of return flow in this area.

The first step in the research program reported in this paper was to make a general survey of headwater and surface runoff from farms in the Boise Valley to find areas of potential problems. The second step was to quantitatively measure the amount of water and nutrients coming onto the land and leaving as surface runoff to evaluate gains or losses of nutrients as a function of irrigation, fertilizer and management practices. Some of the data from both of these studies is included in this paper.

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PROCEDURE

Water Survey

Sites were selected for the collection of water samples in cooperation with personnel from the Nampa-Meridian Irrigation District, the Pioneer Irrigation District, the Black Canyon Irrigation District and the Boise Project Board of Control. A total of 29 farms in the four irrigation districts, representing a wide variety of soil and management conditions, were selected for sampling. The surface water entering and leaving a given area of a field or group of fields was sampled.

Personnel from the irrigation districts collected the water samples at two week intervals during the irrigation season from early May through September of 1970. The samples, which usually consisted of approximately 800 mls of water, were taken in one liter polyethylene bottles. The samples were frozen for storage and transfer to the laboratory in order to prevent changes in the forms of nitrogen due to microbial action.

Water and Nutrient Balance

A gravity-irrigated, row-crop farm located near Nampa, Idaho was selected as the study area for obtaining quantitative data on the total amounts and kinds of nitrogen compounds entering and leaving a farm. Sugar beets and onions were grown on the farm in 1971 with irrigation water supplied from the Boise River, a drainage well, and a deep artesian well. Commercial fertilizer was applied by plowing down, side dressing and through the irrigation water. The site selected for the comprehensive 1971 study was one of the sampling sites for the 1970 survey.

Water flows were measured using cipolletti weirs and a Parshall flume in conjunction with water stage recorders to obtain continuous flow records of all the water entering and leaving the fields. Surface water samples were collected regularly throughout the growing season and frozen for storage and transfer to the laboratory.

Laboratory Methods

The analyses for the nitrogen forms were started the same day the samples were thawed. The methods of analysis were similar to those given by APHA (1971) and EPA (1971). Nitrate-nitrogen was determined by the phenoldisulfonic acid method after removal of any chlorides with silver sulfate. Ammonia-nitrogen was distilled into 1% boric acid using MgO and the distillate analyzed by nesslerization. Organic-nitrogen was determined in the residue after ammonia distillation by the standard Kjeldahl digestion and distillation with nesslerization of the boric acid distillate. The results are reported as parts per million (ppm) of elemental nitrogen.

RESULTS AND DISCUSSION

An example of the relationship generally found in the 1970 survey between the nitrogen concentration in headwater and surface runoff at the various sites surveyed is illustrated in Figure 1. It can be seen in Figure 1 that the concentration of nitrate-nitrogen in the surface runoff from the sampling site differed little from the concentration in the headwater entering the site. This was the case at various sites even though the concentrations varied with the site and with sampling date. Bondurant (1971) obtained

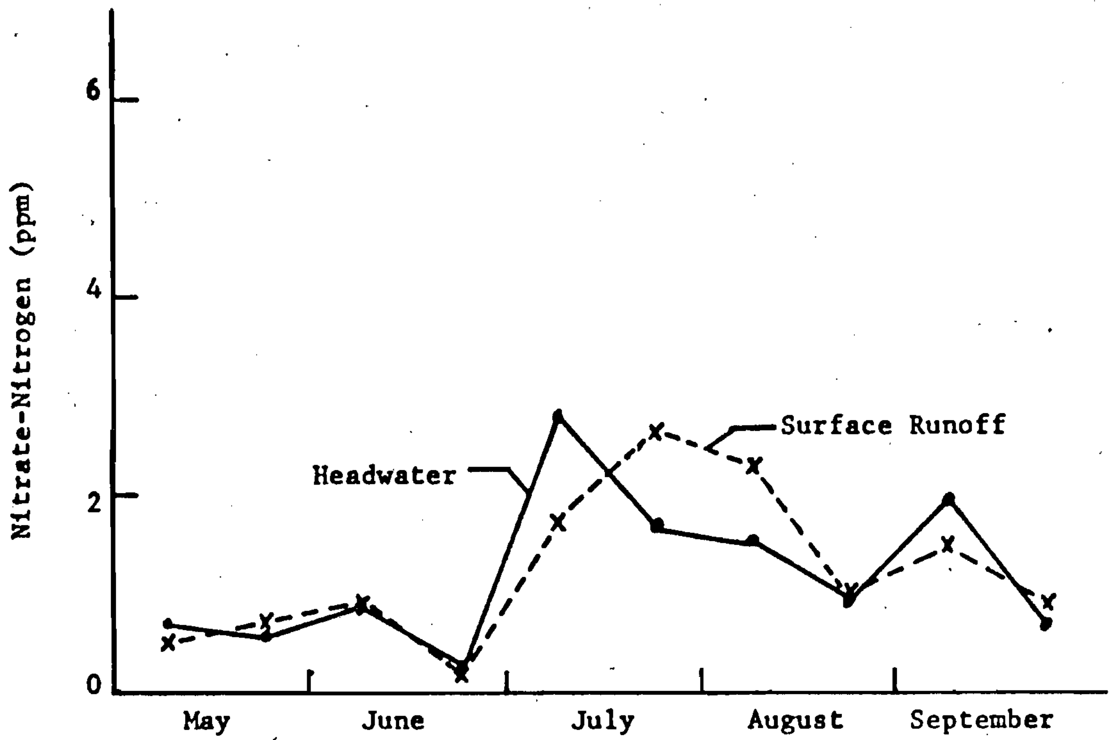

Fig. 1. Nitrate-nitrogen concentration in the surface water at a site during the 1970 water survey.

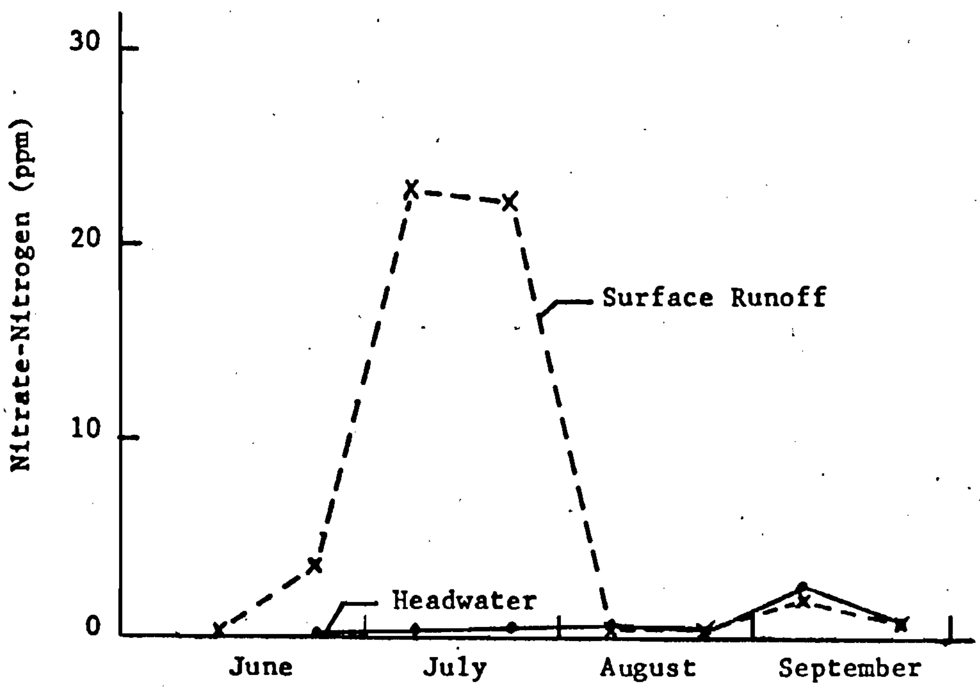

Fig. 2. Nitrate-nitrogen concentration in the surface water at a site with high concentration in runoff during the 1970 water survey.

similar results at his study site near Paul, Idaho.

However, there were infrequent occasions during the survey when the surface runoff samples contained a significantly higher concentration of nitrogen than the headwater samples. An example of data obtained at a site where this occurred is shown in Figure 2. For the samples taken during July, the concentration of nitrate-nitrogen in the surface runoff from the site was about 22 to 23 ppm while the concentration of the same constituent in the headwater was about 0.2 to 0.6 ppm. During the remainder of the irrigation season, the surface runoff and headwater contained about the same concentration of nitrogen.

An investigation into the cultural practices used at the sites where there was an occasional increase in the nitrogen concentration in the surface runoff over the headwater suggested that some of the increase might be due to the addition of fertilizer materials directly into the irrigation water. There was no way to evaluate the significance of the ocasional increases in nitrogen in the runoff since no water flow measurements were made during the survey and the sampling was done at two-week time intervals. Thus it was decided that an investigation should be conducted where all the water entering and leaving a farm could be measured and samples taken regularly for analysis. This was done during the 1971 growing season.

One of the 1970 survey sites was selected for the comprehensive water and nutrient balance study. The nitrate-nitrogen data obtained for this site during the 1970 survey are presented in Figure 2. The concentrations of nitrate-nitrogen in samples of headwater and surface runoff taken on about the same dates in 1971 as in 1970 are plotted in Figure 3. As can be seen, a similar increase in the concentration of nitrate-nitrogen in surface runoff over headwater occurred in both years. Also, the concentrations of nitrate-

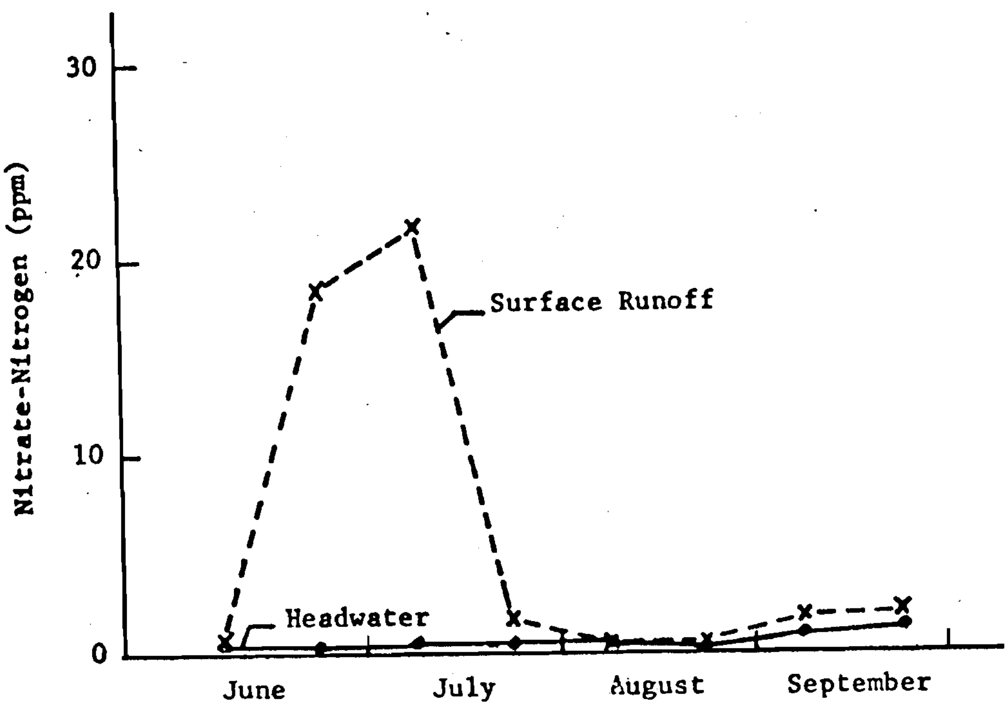

Fig. 3. Nitrate-nitrogen concentration in the surface water at two week intervals at the 1971 study site.

nitrogen were about the same for both years. The addition of fertilizer nitrogen to the irrigation water is known to have occurred in the late June and early July sampling dates in 1971.

A digital computer was used to sort and analyze the data from the 1971 study. Two-hour time increments were used for sorting and presentation so that various phenomena could be analyzed during periods of changing flow and/or concentrations. Such a detailed description of one irrigation set is given in Table 1. The concentration data for the 10-12 a.m. time period are the data points shown for late June in Figure 3.

Table 1. Nutrient and water balance for one 24-hour irrigation set on onions on June 22.

Time Interval	ppm NO_3-N		Inches Water		lb/Acre NO_3-N	
	On	Off	On	Off	On	Off
6-8 a.m.	15.2	----	.103	---	.354	---
8-10 a.m.	15.2	17.6	.105	.022	.360	.088
10-12 a.m.	0.1	18.4	.106	.046	.002	.192
12-2 p.m.	0.1	2.3	.100	.047	.002	.025
2-4 p.m.	0.1	1.2	.110	.050	.003	.014
4-6 p.m.	0.1	0.1	.111	.053	.003	.001
6 p.m. - 8 a.m.	0.1	0.15	.655	.432	.013	.017
Totals	---	----	1.29	.65	.737	.337

It can be seen in Table 1 that the fertilizer was added to the irrigation water very early in the set and fertilizer addition was stopped when surface runoff started. Table 1 also shows that the concentration of nitrate-nitrogen in the surface runoff was highest when beginning surface runoff flow rates were low. Thus, the total pounds of nitrogen lost by surface runoff was kept to a minimum. The irrigator was able to gain maximum use of fertilizer in irrigation water by applying the fertilizer at the beginning of the set when soil infiltration rates were the greatest. From the totals presented in Table 1, it is apparent that the overall nitrogen application efficiency is related to the water application efficiency.

Seasonal totals are presented in Table 2 for the beets and Table 3 for the onions. The total quantities of water applied and the surface runoff are presented along with the total quantities of the three nitrogen forms in the applied and runoff water. The net input was calculated as the difference between the total entering the fields and the total which ran off the fields.

Table 2. Season Totals For Sugar Beets In 1971.

	Water Inches	NO_3-N lb/Acre	NH_3-N lb/Acre	Organic-N lb/Acre
Applied	29.8	4.57	2.77	2.04
Runoff	9.6	1.77	0.54	2.16
Net Input	20.3	2.80	2.23	-0.12
Input:Applied	.68	.61	.80	-.06

Table 3. Season Totals For Onions In 1971.

	Water Inches	NO_3-N lb/Acre	NH_3-N lb/Acre	Organic-N lb/Acre
Applied	35.7	9.31	4.70	3.29
Runoff	14.4	3.96	1.59	3.79
Net Input	21.3	5.35	3.11	-0.50
Input:Applied	.60	.57	.66	-0.15

The ratio of net input to applied water and nutrients is presented in Tables 2 and 3 to indicate what fraction of the applied water or nitrogen stayed on the fields. The input:applied ratio for nitrate-nitrogen was just slightly less than the water ratio indicating that, overall, there was a very slight increase in the nitrate-nitrogen concentration in the surface runoff over the headwater. The net input:applied ratio for ammonia nitrogen was larger than the ratio for the water indicating that, in general, there was a lower concentration of ammonia in the surface runoff than in the headwater.

The organic form of nitrogen was the only one which showed a net loss from the fields over the total season. This was due to the organic matter which was associated with the sediment loss. There was a net loss of about 954 pounds of sediment per acre from the beets and about 3207 pounds per acre from the onions over the season. This appreciable sediment loss carries with it some of the organic nitrogen.

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