CONJUNCTIVE AND EXCLUSIVE USE OF SHALLOW GROUNDWATER FOR IRRIGATION OF SPRING WHEAT

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ABSTRACT

The use of drainwater for irrigation is a viable technology both for improving overall irrigation efficiency and for protecting water quality by reducing the mass output of salts and trace elements from irrigated areas. This was demonstrated in a field study at Newlands Agricultural Research Center in Fallon, NV by growing spring wheat (*Triticum aestivum*) under four irrigation water treatments. The four treatments were: 1) the exclusive use of canal water applied during the day; 2) the exclusive use of drainwater applied during the day; 3) the exclusive use of drainwater applied during the night; and 4) the conjunctive use of drainwater and canal water beginning with a day-time application of drainwater and finishing with canal water. The drainwater came from a shallow aquifer which had elevated levels of salinity and boron. The effects on crop yield of boron and salts applied with drainwater treatments were of primary interest. The field was divided into four blocks representing different soil conditions. Each block was divided into four plots and each plot was randomly assigned one of the four treatments. The growth response to these water qualities was evaluated by weighing plant samples harvested four times during the growing season. The hypothesis that daytime irrigation with drainwater would significantly reduce growth of spring wheat was rejected. The use of drainwater for irrigation appears technically feasible and offers opportunities for improving irrigation efficiency and for reducing the mass output of salts and trace elements from the Newlands Project.

INTRODUCTION

The Newlands Project in the Fallon area of Nevada was among the first irrigation projects authorized under the Federal Reclamation Act of 1902 (Warne 1973). After water deliveries began, the water table rose as much as 18 m. Drainage ditches were needed to alleviate waterlogging and salinization problems. For decades surface and subsurface drainage waters have discharged into endangered wetlands, including the Stillwater Wildlife Management Area (SWMA), to the

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south, east, and north of the irrigated area. Prior to the creation of the Newlands Project, the Carson River provided a safe water supply to these wetlands.

Water in the SWMA can be of poor quality, adversely affecting aquatic life, and trace element concentrations exceed Federal and State criteria (Lico 1992; Hoffman 1992). A program is underway to acquire irrigation water rights for exclusive use in the wetlands (USDI 1993). The use of drainwater for irrigation was demonstrated as an emerging technology for drainage reduction and water quality protection (Faulkner 1996) and is herein extended to the conjunctive and exclusive uses of canal water and drainwater.

In the dispute over water for wetlands, preoccupation with water quantity ignores the quality issues. River water is undiminished in quality whereas drainwater contains the accumulating salts from evapoconcentration following irrigation and from dissolution of salts and trace elements from minerals in the shallow aquifer. The use of drainwater for irrigation has the potential to exchange drainwater for river water and reduce the contamination of wetlands.

The objective is to demonstrate the hypothesis that day-time irrigation with drainwater will significantly reduce growth of spring wheat.

METHOD

Statistical Design

The experiment was designed as a completely randomized design with 4 replications and 3 subsamples per plot (4 replications * 4 treatments * 3 subsamples/plot = 48 samples). The field was divided into 4 blocks with one wheel line per block containing 4 plots. Statistical analysis indicated that there was not a significant block effect and later analyses considered blocks as replications. The single treatment factor was 4 qualities of irrigation water (Cd, Dd, Dn, DdCd). The experiment was designed to test:

H_0: $\mu_{Cd} = \mu_{Dd} = \mu_{Dn} = \mu_{DdCd}$

$H_{alt.}$: At least one mean is significantly different.

Treatments: The study used the following four irrigation treatments:

Cd: A control treatment which was irrigation with canal water applied during the daytime.

Dn: Drainwater applied during the night.

Dd: Drainwater applied during the day.

DdCd: A conjunctive use of drainwater and canal water where the drainwater was applied for one-half the time of an irrigation event and finished with canal water.

See Fig. 1 for the treatment plot arrangement.

The hypothesis was the Dd treatment would have the lowest yield because of boron concentration and salinity of the water. Dn was included to reduce the chance of leaf burn. The DdCd treatment was included to rinse the plant foliage with canal water after using drainwater to reduce the possibility of leaf burn. The Cd component filled the upper half of the soil column with the less saline canal water. This is especially advantageous because plants preferentially draw water from the upper portion of the root zone.

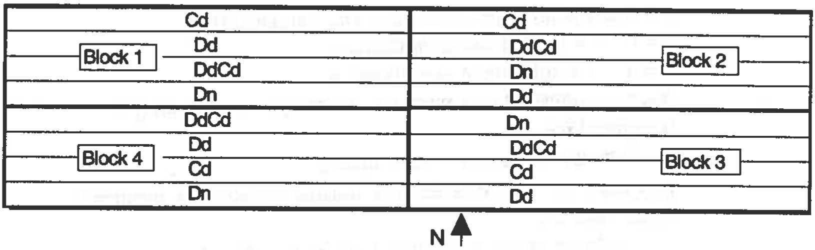

Fig. 1: Arrangement of Treatment Plots

In keeping with Rhoades (1989) recommendations to keep drainwater and canal water separate so high quality water can be preserved for situations where blended water would not be of adequate quality, drainwater was not blended with canal water.

<u>Sampling</u>: A sample site was randomly chosen along a transect running through the center of a plot, parallel to the wheel lines and crop rows. The first 26 m (80 feet) adjacent to the north-south mainline separating blocks 1 and 4 from blocks 2 and 3 were excluded to reduce effects of overlapping spray from a different treatment. The last 13 m (40 feet) farthest from the north-south mainline were also excluded because the application zones did not overlap in the same manner as they did in the rest of the plot. The remaining length available for sampling was 129 m (400 feet) within experimental plots measuring 168 m (520 feet) in length. Subsamples were taken at 3 randomly selected locations along the transect on each sampling date. A sample site consisted of a 1-m length of 1 row of wheat, clipped at ground level. The entire aerial portion was collected, dried, and weighed.

Samples were collected at 4 growth stages. The first samples were collected after all plants had been established using only canal water and before applying any drainwater. This made it possible to test for variability in the field other than the variability caused by the treatments. The second sampling was done 4 weeks later when the plants were in the leaf sheath stage, a time when plants are more sensitive to boron. The third sampling occurred 13 weeks after planting when most plants were in the mid-milk to early-dough stage. The fourth sampling was at harvest time, 17.5 weeks after planting. An additional (fifth) sample was obtained of the grain contained in the fourth sample.

Statistical Model: The experiment used the following statistical model:

$$Y_{ijk} = \mu + A_i + \varepsilon_{ij} + s_{ijk}$$

where:

i = water quality treatment (Cd, Dd, Dn, DdCd)
$j = 1\ldots4$ = replication identification
$k = 1\ldots3$ = subsample identification
Y_{ijk} = response of treatment i on k^{th} sample in replicate j
μ = grand mean
A_i = effect of i^{th} level of water quality
ε_{ij} = random error, independent, normal distribution, mean = 0, equal variance
s_{ijk} = subsample error, independent, normal distribution, mean = 0, equal variance.

The data were analyzed using the SAS® (Statistical Analysis Systems version 6.11) macro MXANOVA (Fernandez 1997). MXANOVA tested the treatment effects and computed the corrected mean-square error for treatment effects using the treatment effects within replications (REP(TRT)) as the correct error term. MXANOVA then produced a box plot of each treatment response, checked the ANOVA (analysis of variance) normality assumption by producing a normal probability plot; and using the D'Agostino-Pearson Omnibus Test, checked for outliers and influential observations within a plot and the Cooks D statistic, and checked the equal variance assumption with Levene's test. The treatment arrangements were randomly chosen to ensure their independence. The ANOVA assumptions were verified using PROC GLM (standard or robust) and the ANOVA was performed using PROC MIXED (or ROBMIX). The robust analysis iteratively weights influential observations to remove outliers. MXANOVA also produced tabular output and a plot of treatment mean differences and confidence intervals as well as output showing the treatment mean differences and the confidence intervals for a given confidence level. Also included in the output were the least-square treatment means, standard errors, and pair and or group comparisons.

Field Preparation

The study area was the central 4.5 ha (146 m x 315 m) of a 9 ha field The entire field had 15 parallel, corrugated plastic drains buried 2 m deep and spaced 37 m apart. Drainwater was collected in a sump and pumped into a 680 m^3 surface reservoir as the source of water for plots receiving drainwater treatments. A centrifugal pump supplied the sprinklers with pressurized drainwater and another pump at the northwest corner pumped canal water.

On March 31, 1996 the study area was planted with spring wheat variety Penewawa at a seeding density of 124 kg/ha (110 lbs/ac). This was the second consecutive season for wheat to be planted on the site. Local and NARC practices, typically dictate that alfalfa is cropped for approximately 7 years followed by 1 - 2 years of small grains before reverting to alfalfa. The seeding density and choice of Penewawa were based on recommendations from the County Cooperative Extension. At planting, 98 kg/ha (87 lbs/ac) of urea was applied based on recommendations derived from soil sample analysis from the Helena Co., a private agricultural service company with a representative in the Fallon area. The same firm performed a tissue analysis of samples 8 weeks after planting and recommended the application of Bayfolan® Plus, a crop mix fertilizer, (N:P:K=11-8-5 plus micronutrients) at 4.7 L/ha (1/2 gal/ac). The application was performed a week later together with Weedestroy®, a 2,4-D based herbicide. The harvest was on 31 July, 17.5 weeks after planting.

Irrigation Scheduling

A new irrigation cycle began when estimated D_i reached 71 mm or after 7 days, whichever occurred first. The amount to apply was based on the estimated ET by employing the FAO Class A pan method of Doorenbos and Pruitt (1977):

$$ET_0 = K_{pan} * E_{pan}$$

where:

ET_0 = reference evapotranspiration (mm)
K_{pan} = pan coefficient (function of wind speed, relative humidity, pan location, and upwind fetch)
E_{pan} = depth of water (mm) evaporated from a Class A pan over 7 days

and ET_{crop} is:

$$ET_{crop} = K_{crop} * ET_0$$

where:

K_{crop} = the crop coefficient (Guitjens, 1990) and
ET_{crop} = crop evapotranspiration (mm) over 7 days

The weekly irrigation demand was calculated as:

$$D_i = (ET_{crop}/0.70) - D_{rain}$$

where:

D_i = depth of irrigation demand (mm)
0.70 = the assumed irrigation efficiency of the system and
D_{rain} = depth of rain (mm).

Estimated soil water used by the crop during one week was replaced during the following week's irrigation cycle.

The root zone water holding capacity was estimated at 10 cm (4 in) (Guitjens, 1992). Meyer and Green (1980) report a significant reduction in leaf growth when the available soil water dropped below 45% of the holding capacity. They concluded that the general practice of allowing 50% depletion before the next irrigation is a safe practice. The irrigation scheduling was based on this 50% depletion. A new irrigation cycle began each week or when the evaporation pan model estimated ET_{crop} to have reached 5 cm (2 in). There were 18½ irrigation cycles in 16 weeks of irrigation. The shortest cycle was 4 days during the period of warm weather and high crop water demand. The crop was allowed to dry during the last 1½ weeks before harvesting. During the last half cycle the entire field received half the estimated D_i.

Sprinkler System

Sprinkler irrigation was used during the 1996 season. Four sprinkler lines were used , 1 per block, spaced 18.2 m (60 ft) between line positions and 12.1 m (40 ft) between nozzles. The nozzles were set for semi-circle application. After the D_i was determined for a cycle, one-half was applied with the sprinkler lines stationed on the south edge, and spraying north into the plots. After all plots received one-half the D_i this way, nozzles were reversed to face south and plots were irrigated with the lines on the north edge and spraying south. This allowed plots to go a maximum of 4 days without irrigation. The water application rate was 2 cm/hr (0.8 in./hr) with the pumping rate of 2,270 l/min. (600 gpm).

Water Chemistry

Samples of both canal water and drainwater were taken at 12 weeks after planting and at harvest for analysis of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, Cl^{-}, NO_3^{-}-N, HCO_3^{-}, As, Fe, Cu, B, Se, and total P by the EPA approved Nevada State Health Laboratory in Reno. Dissolved oxygen, EC and pH were measured on site biweekly during the latter portion of the experiment.

RESULTS AND DISCUSSION

Statistical Analysis

Box plots indicate that the median value of the Dd treatment response is greater than those of all other treatments during all samplings when using both standard and robust analysis. Only Sample 1 had an outlier. However, the Cooks D test identified an additional outlier in Sample 2 and two outliers in Sample 3. Huber's Iteratively Weighted Robust ANOVA portion of SAS reduced the influence of outliers in Samples 1 and 2. Sample 3, however, retained one outlier.

ANOVA Assumptions: According to Levene's test for equal variance and standard analysis, the equal variance assumption was not met for Sample 1 ($P = 0.0028$) and Sample 3 ($P = 0.040$). The validity of Levene's test has been ascertained only for single factor analysis and it remains to be seen if it is valid for mixed data. Therefore, plots of the residuals (observed value - mean value) are used to show variance among treatments. The absence of a fan or diamond trend in the plots indicates that equal variance may still be assumed. The large variation with standard analysis is resolved by the robust analysis. Robust analysis allowed Sample 3 to meet the criterion ($P = 0.052$) but Sample 1 still did not improve, in fact the problem worsened ($P = 0.00074$). This can be corrected by transforming the data but when working with mixed data, such as in this study, data transformation is not appropriate. The D'Agostino-Pearson Omnibus Normality Test verified the normality assumption and checked the skewness and kurtosis. Standard analysis found the normality assumption was not met only for Sample 3 ($P = 0.000068$). Sample 3 was significantly skewed ($P = 0.018$) and the kurtosis was significant ($P = 0.00022$). Robust analysis rectified the normality assumption ($P = 0.076$) and the skewness ($P = 0.42$) and the kurtosis was greatly improved ($P = 0.034$).

ANOVA Results: The treatment effect when using robust analysis was not significant ($P > 0.05$) for any sampling date except for Sample 4 ($P = 0.0215$); although it was borderline for Sample 3 ($P = 0.0560$) and Sample 5 ($P = 0.0640$). Standard analysis revealed the treatment effect was significant for Sample 4 ($P = 0.0144$) and Sample 5 ($P = 0.0316$). The experimental error was significant for all cases except the standard analysis of Sample 4 ($P = 0.1733$).

When comparing pairs of treatments using the differences of least-square means, there were no significant differences among treatment responses for Samples 1 and 2. Means and their upper and lower confidence intervals are listed in Table 1. Response to treatment Dd was significantly greater than DdCd at Samples 3, 4, and 5 for both robust and standard analysis. Response to treatment response Dd was also significantly greater than Dn at Sample 3 according to both methods of analysis. Also for Sample 3, Dd was significantly greater than Cd with robust analysis but the significance was not present with standard analysis. The reverse was true for Sample 4, the Dd was significantly greater than Cd with standard analysis but not with robust analysis. Both robust and standard analysis found significantly greater yields for Dd than Cd for Sample 5. Only standard analysis found that Dd had a significantly higher yield than Dn. Of most interest for all of these comparisons is that only the Dd treatment was at any time significantly greater than any other treatment.

Table 1: Treatment Response Means, Standard Errors and Confidence Intervals

Treatment	Sample	Lsmean	Standard Error	95% Confidence Interval		P-value
				Lower	Upper	
Cd	1	4.8333	0.6956	3.3178	6.3488	0.0001
Dd	1	4.8333	0.6956	3.3178	3.3488	0.0001
DdCd	1	3.4167	0.6956	1.9012	4.8322	0.0004
Dn	1	3.0833	0.6956	1.5678	4.5988	0.0008
Cd	2	36.167	7.1054	20.685	51.648	0.0003
Dd	2	39.083	7.1054	23.602	54.564	0.0001
DdCd	2	33.333	7.1054	17.852	48.812	0.0005
Dn	2	36.750	7.1054	21.269	52.231	0.0002
Cd	3	60.667	11.175	36.318	85.015	0.0002
Dd	3	88.167	11.175	63.818	112.52	0.0001
DdCd	3	52.667	11.175	28.318	77.015	0.0005
Dn	3	52.583	11.175	28.235	76.932	0.0005
Cd	4	89.583	9.7867	68.260	110.91	0.0001
Dd	4	138.92	9.7867	117.59	160.24	0.0001
DdCd	4	95.583	9.7867	74.260	116.91	0.0001
Dn	4	118.75	9.7867	97.427	140.07	0.0001
Cd	5	25.042	4.724	14.749	35.335	0.0002
Dd	5	45.158	4.724	35.165	55.751	0.0001
DdCd	5	25.375	4.724	15.082	35.668	0.0002
Dn	5	29.958	4.724	19.665	40.251	0.0001

Note: Mean values (g) are for raw subsamples, to convert to g/m^2 multiply mean weights by 6.56

Figure 2 shows the mean weights of the four treatment responses at each sampling. Sample 5 shows average grain yields of 1.6-3.0 Mg/ha depending on the treatment.

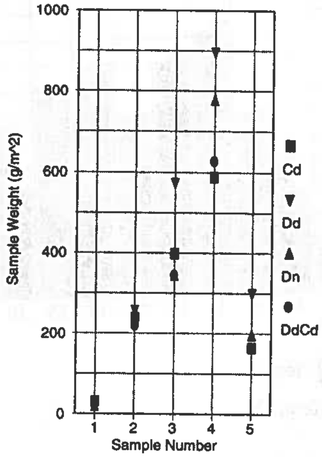

Fig. 2: Mean Weights by Treatment at Each Sampling

Yields

World-wide the mean yield for wheat is approximately 4 - 6 Mg/ha (Doorenbos and Kassam, 1979). The Nevada Agricultural Statistics Service quoted the mean yield for the Fallon area in 1996 as 4.0 Mg/ha. This study, using the results of Sample 5, had average yields ranging from 1.64 to 2.98 Mg/ha depending on treatment. Grain yields ranged from a low of 29.5 g/m^2 (0.295 Mg/ha) for a Cd treatment subsample to a high of 476 g/m^2 (4.76 Mg/ha) for a Dd subsample. Guitjens (1992) showed that the variability within fields contributes to lower average yields. Crop variability can be caused in part by soil heterogeneity which for example resulted from shifting river channels and lake levels.

Causes of the low yield in 1996 are unclear. Although the type sample for Sagouspe loamy sand was obtained from NARC, and the Churchill County soil specialist considered NARC to have uniform soils, the north portion of the field is sandier than the south. Water often ponded on the southwest plots (block 4) for several consecutive days. The yield of Sample 5 was greatly affected by a severe weed infestation despite the herbicide spraying program.

Before irrigating under different treatments, a benchmark was established with Sample 1. Despite the fact that Sample 2 was taken at a lifestage when wheat is sensitive to boron and those effects might be expected to be seen in the results of Sample 2 or Sample 3, the response to treatment Dd was greater than the response to treatments DdCd and Dn, contrary to the hypothesis that irrigation with drainwater would significantly reduce growth of spring wheat.

Irrigation Scheduling

The water applications as compared to estimated irrigation demand can be seen in Fig. 3. The mean D_a for the season was 130 mm (15%) greater than the seasonal D_i. Nearly all of this excess water was applied during the four weeks labeled 0 through 3 when the soil profile was being filled and excess water could leach salts accumulated from the previous season. Week 8 and Week 9 represent one irrigation cycle and the apparent underirrigation of Week 9 was nullified by

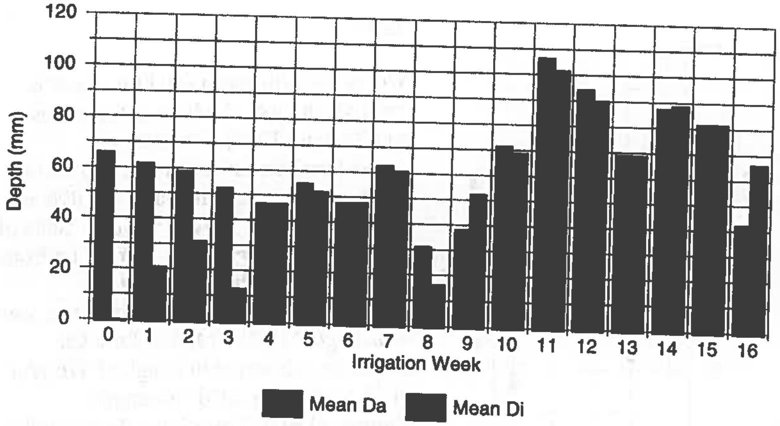

Fig. 3: Mean D_a and Mean D_i

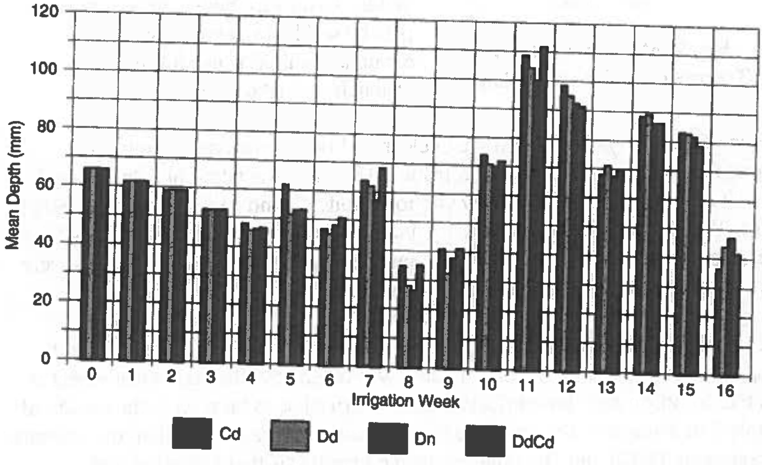

Fig. 4: Mean D_a per Treatment

crediting Week 8 with a greater D_a. The same variations which caused the D_a to deviate from D_i can be seen to cause slight differences in the amount of water applied to each treatment (Fig. 4).

The Truckee-Carson Irrigation District (TCID) has been mandated by the federal government to improve its efficiency of operations including water delivery.

Current methods to improve efficiency focus on the canal delivery system. Irrigators are not allowed access to irrigation water again until 2 weeks after irrigating, leaving lateral canals empty until a minimum number of farmers along a canal are ready to irrigate. This is an attempt to minimize canal losses.

On the other hand, very little is being done to improve on-farm irrigation efficiency. One way to improve on-farm irrigation efficiency is to use drainwater for irrigation. Drainwater can be collected, stored, and applied to the same field as was done at NARC, or it can be pumped back into delivery canals to blend with canal water. Increasing efficiency in Fallon reduces irrigation demand for canal water and salt loading in the SNWR and other wetlands. Drainwater transports salts evapoconcentrated in the root zone and mobilizes and transports additional salts and trace elements during percolation to the wetlands.

Improved efficiency involves water conservation which requires producing the same yield with less canal water. Drainwater can be used in place of canal water for irrigation thus conserving canal water. Gould (1992) demonstrated that the mass flux of salt is somewhat proportional to the flux of drainwater. When drainwater is used for irrigation, there is less off-farm drainage and hence less mass flux of salts from irrigated lands. Irrigation with drainwater is a practicable BMP for the control of nonpoint source flow.

Doorenbos and Kassam (1979) list worldwide water use efficiency (WUE) (Equation 1) for irrigated wheat (whether spring or winter wheat is not clear) as 0.8-1.0 kg/m^3 when using actual ET. Musick and Porter (1990) quote 1.0 - 1.2 kg/m^3 for fall- planted spring wheat although it may be as high as1.9 kg/m^3, but

$$\mathrm{WUE} = \left(\frac{\mathrm{yield(kg/m^2)}}{\mathrm{ET(m)}}\right) = \mathrm{kg/m^3} \qquad (1)$$

tests in the Great Plains, Washington and Utah agree with the values given by Doorenbos and Kassam. Using the modeled ET of 0.66 m and an average yield of 0.298 kg/m^2 for treatment Dd, this study had a WUE of 0.45 kg/m^2. The subsample with the highest grain yield (0.476 kg/m^2) was in the Dd treatment. That subsample had a WUE of 0.72 kg/m^3. The subsample with the lowest yield (0.059 kg/m^2) received the Cd treatment and had a WUE of 0.08 kg/m^3. Statistical testing at a field scale rather than on small plots appears to have a confounding influence by creating large variability.

Water Chemistry

Table 2 reports the water chemistry of canal water and drainwater. All the elements and ions listed contribute to salinity. Boron at 1.5 mg/L, which is highly soluble and leaches readily, is at a potentially problematic concentration for wheat in the drainwater. Maas (1990) lists tolerance limits for wheat and alfalfa as 0.75 -

Table 2: Water Chemistry

	22 July, 1996		22 July, 1996		2 Aug. 1996		2 Aug. 1996	
	Canal		Drain		Canal		Drain	
Major Ions	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L
Na^+	17	0.739	284	12.3	17	0.739	284	12.3
Ca^{2+}	18	0.9	47	2.35	18	0.9	43	2.15
Mg^{2+}	5	0.413	9	0.744	5	0.413	9	0.744
K^+	2	0.051	9	0.231	3	0.077	12	0.308
Total P	0.14	0.23	0.54	0.087	0.08	0.013	0.24	0.039
SO_4^{2-}	26	0.578	160	3.56	25	0.56	159	3.53
NO_3^--N	0.2	0.071	12.4	4.43	0.3	0.107	10.7	3.82
HCO_3^-	83	1.36	664	10.9	73	1.20	605	9.92
Cl^-	5	0.26	39	2.05	5	0.26	33	1.74
Trace Elements	(mg/L)		(mg/L)		(mg/L)		(mg/L)	
Fe	0.29		0.10		0.78		0.07	
Mn	0.03		0.03		0.04		0.01	
B	0.1		1.5		0.1		1.5	
Se	NA		0.003		NA		0.006	
As	0.007		0.250		0.008		0.260	
Hardness	66		155		66		145	
Alk.	68		544		68		496	

	1 Jn	16 Jn	28 Jn	6 Jy	13 Jy	20 Jy	1 Ag.	Mean
CANAL								
Temp (°C)	11.4	15	15	16	15.5	16	17.5	15.2
DO (ppm)	9.5	6.6	9.3	8.8	7.3	8.9	9.1	8.5
EC (dS/m)	0.26	0.24	0.24	0.22	0.23	0.22	0.22	0.23
DRAIN								
Temp (°C)	11	16	14.2	13.5	14.5	14	14.5	14.0
DO (ppm)	9.5	5.6	3.6	4.4	3.2	3.0	5.2	4.9
EC (dS/m)	1.53	1.4	1.57	1.5	1.37	1.57	1.44	1.48

1.0 mg/L and 4.0 - 6.0 mg/L respectively, but notes that tolerance varies with climate, soil conditions, and crop variety and makes similar qualifications regarding EC tolerance limits. Boron in the canal water at 0.1 mg/L is not of concern. The EC of the drainwater is also well below the 2.0 dS/m tolerance limit for alfalfa and the 6.0 dS/m limit for wheat (Maas, 1990). HCO^-_3 is the dominant ion in canal water followed by Ca^{2+}, Na^+, SO^{2-}_4, and Mg^{2+}. In drainwater, Na is dominant followed by HCO_3^-, NO_3^--N, SO_4^{2-}, Ca^{2+}, Cl^-, and Mg^{2+}. The Cl^- concentration should not be harmful to alfalfa or wheat (Maas, 1990). Ayers and Westcot (1985) recommend using irrigation water with less than 0.10 ppm As. Drainwater concentrations of As were 0.25 and 0.26 ppm. Fe and Mn are both adsorbed to the soil matrix. Their concentrations are safe for irrigation. The presence of any selenium could be a problem if it evapoconcentrates or biomagnifies in wetlands or if selenium assimilating plants are established in irrigated pasture. Overall, the drainwater should not cause any problems when used as irrigation water.

Once plants are established using canal water, irrigation with drainwater is viable for spring wheat. The drainwater was not detrimental to crop yield. Since wheat is moderately sensitive to B and alfalfa is more tolerant, the B concentration in drainwater will not reduce yields in alfalfa. The high variability within the field Once plants are established using canal water, irrigation with drainwater is viable for spring wheat. This variability is common in the Fallon area and can be taken as representative of local conditions.

CONCLUSION

Irrigation with drainwater did not significantly reduce the yield of spring wheat, contrary to the hypothesis. Of the four treatments, only irrigation exclusively with drainwater during the day produced yields significantly greater than any other treatment. The Dd treatment response was significantly greater than DdCd and Dn at Sample 3, DdCd at Sample 4, and DdCd at Sample 5 according to ANOVA using SAS® standard and robust analysis procedures. Only the standard analysis found that Dd was significantly greater than Cd in Sample 3 and Dn in Sample 5 whereas the robust procedure found a significant difference from Cd in Sample 4.

The use of drainwater for irrigation of spring wheat was shown to be technically feasible. Grains yields based on individual subsamples obtained during Sample 5 ranged from a low of 29 g/m^2 for a Dn subsample to a high of 475 g/m^2 for a Dd subsample. By using drainwater to replace an equal depth of canal water, this study reduced the canal water demand. This method can be sustained over many years since drainwater is not available early in the irrigation season and any accumulated salts are flushed from the soil by using canal water. If this leaching is insufficient, the area receiving drainwater may be changed each year when the accumulated salt concentration necessitates greater leaching than that provided by the early season irrigations alone. The mass flux of salts from irrigated areas is somewhat proportional to the flux of drainwater. Irrigation with drainwater serves as a BMP to reduce non-point source flow of drainwater and a proportional mass flux of salts.

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