NITRATE LEACHING LOSSES UNDER DIFFERENT IRRIGATION FREQUENCIES AND UPTAKE IN CEREAL FOODS

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Modern agriculture is now recognized by both farmers and environmentalists as a significant source of water pollution. Nitrates can cause "Methaemoglobinaemia (blue-baby syndrome)" and "Stomach Cancer" if intake increases from a certain limits. The world health organization (WHO) recommended the maximum admissible concentration (MAC) for drinking water is 11.3 mg L^{-1} NO_3-N (equivalent to 50 mg NO_3^- L^{-1}). Therefore a study was conducted in the Lysimeters measuring 4 x 4 x 4 feet to assess the NO_3-N concentration in water leached through lysimeters soil by applying nitrogen fertilizer (NPK @ 120-100-50 kg ha^{-1}) and different irrigation levels. Three irrigation levels 7.5, 11 and 15 cm were applied to wheat in three irrigations. Leachate water was collected in containers beneath each lysimeter plot and analysis of leachate obtained from Lysimeter plots showed that the NO_3-N concentrations were well below the WHO standards. NO_3-N concentration ranged from 0.19 mg L^{-1} to 13.6 mg L^{-1}. Total volume of water (rainfall plus irrigation) applied to wheat crop was also measured and during 2000-2001 it was 1077 L, 1413 L and 1749 L; while during 2001-2002 it was 780 L, 1119 L and 1455 L from 7.5, 11 and 15 cm irrigation levels, respectively. The concentration of nitrates ranged from 1.26-8.66 mg L^{-1}. The amount of total nitrates in leachate water were 980 mg, 1119 mg and 1405 mg in 2000-2001 and 534 mg, 465 mg and 759 mg from 7.5, 11 and 15 cm irrigation levels respectively. This study clearly showed that nitrate leaching occurred under higher irrigation frequencies but the NO_3-N concentrations in leachate were well below the WHO standards, so the pollution threat from nitrate leaching under Pakistan's existing conditions is not possible.
Key words: Nitrates, irrigation frequency, cereal foods, Pakistan.

INTRODUCTION

The UNEP/WHO assessment of water quality programme (UNEP/WHO, 1998, 1987) states that radical changes are needed to reverse the trend in nitrate pollution and stop it from becoming a large-scale and potentially global water quality problem. Higher ingestions in form of nitrates, nitrites and nitrosamine may cause many health hazards like methaemoglobinaemia and stomach cancer in humans specially infants (Wild, 1997). Nitrates in cereal straw and vegetables may be equal or greater source of nitrate ingestion than water (Kornberg, 1979). Methaemoglobinaemia is a condition that mostly affects babies less than six months old (House of Lords, 1989). It is caused by reaching of NO_3^- or NO_2^{--} in the blood stream with haemoglobin to form methaemoglobin. This normally accounts for less than 2% of total haemoglobin but when levels rise above 10 % the flow of oxygen to body tissue is restricted and the child develops a characteristic blue tinge which is known as "*blue baby syndrome*". Death can result on some where in the range of 45-65 % of haemoglobin has been converted. NO_3^- or NO_2^{--} can also cause gastro-intestinal infections and stomach cancer (Pretty, 1998; Preussman and Stewart, 1984).

Nitrate (NO_3^-) is short for sodium Nitrate $NaNO_3$, a naturally occurring (not man- made) substance in vegetables, drinking water, soil and human saliva. The risk of nitrate leaching from arable land increases considerably post-harvest when plant uptake of nitrogen is zero but N release through mineralization is higher. Some researchers (Addiscott, 1990) reported that the source of nitrate is the mineralization rather than fertilizer N remaining in the soil. Different arable crops leave different amounts of nitrogen residues in the soil; Macdonald *et al.*, (1989) found the pattern: Potatoes > oilseed > rapeseed > winter wheat for nitrogen residues. A number of studies have shown that nitrate losses increase significantly where the amount of N fertilizer added is large. As nitrogen becomes less limiting, each additional increment of N applied is less efficient at higher yields; excessive amounts of nitrogen can result in a decrease in yield.
Most of the NO_3^- or NO_2^{--} are leached with water and comes from fertilizer N or other sources (organic matter and crop residues etc.). Several factors including tillage method, Crop rotation, irrigation amount and method of application, and rate of N fertilizer affect NO_3 leaching (Burkat and Koplin, 1993; Kanwar *et al.*, 1998). When N fertilizer is applied to soil it is nitrified into NO_3^- and being negatively charged, it leaches down gradually with irrigation water and

reaches to the ground water and cause pollution. Fertilizer N applied to soil surface leaches to ground water through the soil profile/column (Baker and Johnson, 1981; Randall and Irgavarapu, 1995; Weeds and Kanwar, 1996). The quantity of NO_3 leached from soil directly relates to the drainage volume (Ritter and Managor, 1985; Borin *et al.,* 1998) and controlled irrigation can markedly reduce NO_3 losses through leaching (Burt and Trudgill, 1993).

In Pakistan information regarding the irrigation and N fertilizer application on water pollution due to NO_3 leaching is limited. Some researcher (Niaz *et al.*, 2003; Niaz *et al.*, 2004) have reported that due to less N fertilizer use and low water application rate, there is no chance of ground water pollution from NO_3 leaching under these climatic conditions. However the increased use of N fertilizer, increasing cost of fertilizer and public concern about NO_3 pollution of water necessitates for assessing the effect of irrigation levels on NO_3 movement through soil profiles. Therefore, the objective of this study was to assess the effects of recommended N fertilizer use on magnitude of NO_3 leaching to ground water and NO_3-N concentrations in the leachate under varying levels of irrigation.

MATERIALS AND METHODS

This study comprises a series of lysimeter experiments conducted at Soil Chemistry Section, Ayub Agricultural Research Institute (AARI), Faisalabad during 2000-2002. Wheat crop was sown in permanently constructed cemented lysimeters measuring 4 x 4 x 4 (Figure 1).

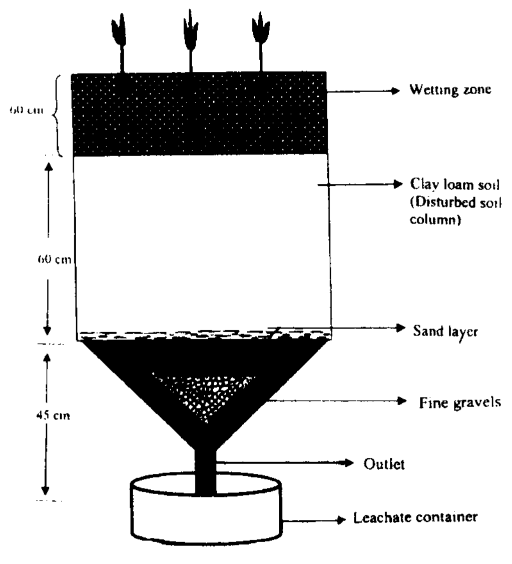

FIGURE 1 SCHEMATIC DIAGRAM OF COLUMN LYSSIMETERS DESIGN AND INSTALLATION

Lysimeters were filled with clay loam soil (disturbed soil column). Three irrigation levels, 3", 4.5" and 6" were applied to wheat crop. The standard practice of irrigation level (used by local farmers) is about 3". The recommended dose of N, P_2O_5 and K_2O was applied @ 120-100-50 kg ha^{-1} to wheat crop. Nitrogen, as urea was applied at sowing and with 1st irrigation to wheat while P_2O_5 as single super phosphate (SSP) and K_2O as sulphate of potash were applied at sowing. Before sowing of wheat crop soil samples were taken from each lysimeter plots to analyze the physico-chemical properties of soil. A composite soil sample was analysed for EC_e (Rhoades, 1982), pH_s (McLean, 1982), Organic matter (Nelson and Sommers, 1982), total soil N (Tecator, 1981) and particle size analysis (Gee and Bauder, 1986).

Table-1. Physico-chemical analysis before sowing of wheat.

Physico-chemical characteristics (0-15 cm depth)	Irrigation levels (cm)		
	7.5	11.0	15.0
EC_e (d Sm^{-1})	1.07	1.10	1.11
pH_s	7.65	7.60	7.65
O.M (%)	0.67	0.73	0.79
Saturation percentage (%)	35.6	35.8	35.1
Total N (%)	0.032	0.030	0.038
Textural class	Clay loam		

Table 2. NO_3-N concentration (mg kg^{-1}) in soil profiles before sowing of wheat.

Soil depths (cm)	Irrigation levels (cm)		
	7.5	11.0	15.0
0-15	9.10	7.02	8.32
15-30	6.85	8.53	6.10
30-60	8.07	10.85	11.60
60-90	6.28	5.30	7.35
90-120	7.05	3.50	4.03

Two wheat crops were taken during 2000-2002 and was sown at uniform moisture level. After germination, all plots were irrigated with measured quantity of water. The treatments were replicated thrice in a completely randomized design. Meteorological data was also recorded at the observatory of Plant Physiology Section, Ayub Agricultural Research Institute, Faisalabad. Plant protection measures were taken upto maturity. The soil sampling was done before each irrigation and after harvest for the determination of NO_3 movement in soil profiles. The crop evapo-transpiration (ET) was calculated by multiplying potential evapo-transpiration (ET_P) by the crop co-efficient, $K_C\varnothing$ (Jensen and Sletter, 1965).

$$ET = K_C\varnothing \times ET_P$$

The crop co-efficient, K_C for each crop varies with growth stage (Ali, 1986). The potential evapo-transpiration (ET_P) was calculated by following the formula of Hargreaves and Samani (1985).

$ET_P = 0.0023 \times R_A \times TD^{½} (T_C + 17.8)$, in which

ET_P = Average potential evapotranspiration (mm/day)

R_A = Extra terrestrial radiation (mm/day)

TD = Av. Maximum temperature – Av. Minimum temperature (^{O}C)

$$T_C = (T_{max} + T_{mini}) / 2$$

Crop ET was divided by field application efficiency of 0.7 for working out irrigation requirements (Ali, 1986). The depth of irrigation water was converted into the time of water application by continuity equation.

$$qt = 28\ ad$$

Where,

q = discharge of water in L/sec.

t = Time required to irrigate the plot area in hours.

a = Area irrigated in hectares.

d = Depth in cm.

The uniform irrigation of 5.0 cm was applied to all irrigation treatments at rauni (application of water for the preparation of lysimeter soil for sowing of wheat) and then three irrigation levels (3", 4.5" and 6") were applied to wheat crop. Quantity of irrigation water being applied to 4' x 4' x 4' lysimeter plots were measured in liters. Before each irrigation, gravimetric water contents/moisture contents were determined for each depth (Lowery et al., 1996). Direct sampling of soil and soil water / leachate was adopted for analysis techniques. Samples were taken by coring and putting containers beneath lysimeters and the amount and chemical composition of the water was determined by

Table-3. Effect of irrigation levels on nitrate leaching, volume of leachate and amount of nitrates leached during 2000-2001.

Treatments (Inches)	NO_3-N Conc. (mg L^{-1})	Total volume of Leachate (L)	Total Nitrates leached (mg)	Ranges of NO_3-N Conc.
3.0	5.85 ^{NS}	175 B	980 B	2.29-7.82
4.5	5.83	193 AB	1119 B	0.19-8.02
6.0	6.39	223 A	1405 A	1.51-13.60
LSD	0.918	29.73	83.6	-

Table 4. Effect of irrigation levels on nitrate leaching, volume of leachate and amount of nitrates leached during 2001-2002.

Treatments (Inches)	**NO_3-N Conc. (mg L^{-1})**	**Total volume of Leachate (L)**	**Total Nitrates leached (mg)**	**Ranges of NO_3-N Contents**
3.0	5.87 NS	91 B	534 B	1.85-8.40
4.5	4.27	109 B	465 B	2.86-8.61
6.0	5.13	148 A	759 A	3.01-7.94
LSD	1.83	19.73	108.33	-

Table 5. Irrigation amount, rainfall, total irrigation water applied and NO_3–N content in wheat plant (2000-2001).

Treatments (Inches)	**Irrigation amount (mm)**	**Rainfall (mm)**	**Total irrigation water applied (L)**	**Plant NO_3-N content (mg kg^{-1})**
3.0	225	133	1074	498
4.5	338	133	1413	574
6.0	450	133	1749	542

Table 6. Irrigation amount, rainfall, total irrigation water applied and NO_3–N content in wheat plant (2001-2002).

Treatments (Inches)	**Irrigation amount (mm)**	**Rainfall (mm)**	**Total irrigation water applied (L)**	**Plant NO_3-N content (mg kg^{-1})**
3.0	225	34.6	780	576
4.5	338	34.6	1119	597
6.0	450	34.6	1455	589

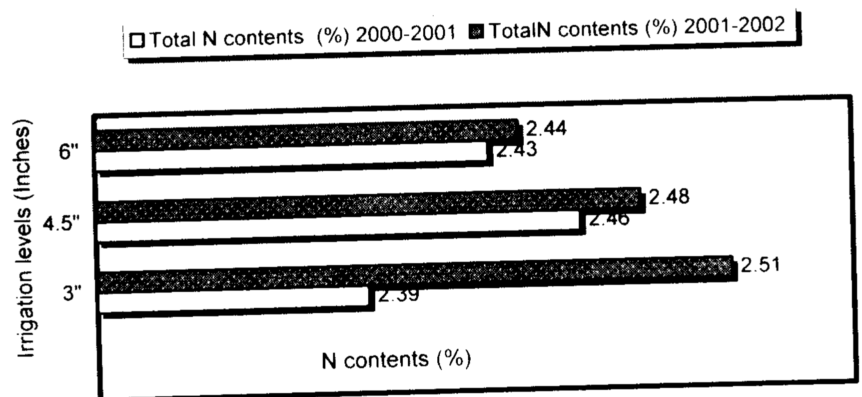

Figure 2. Effect of irrigation levels on N Contents of wheat.

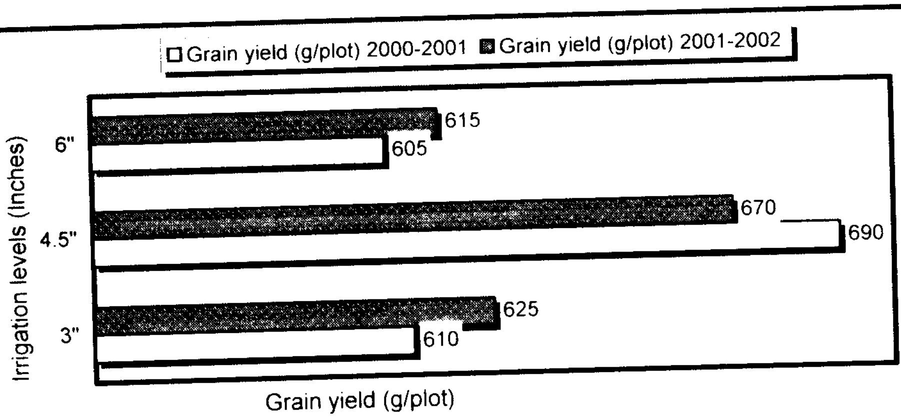

Figure 3. Effect of irrigation levels on grain yield of wheat.

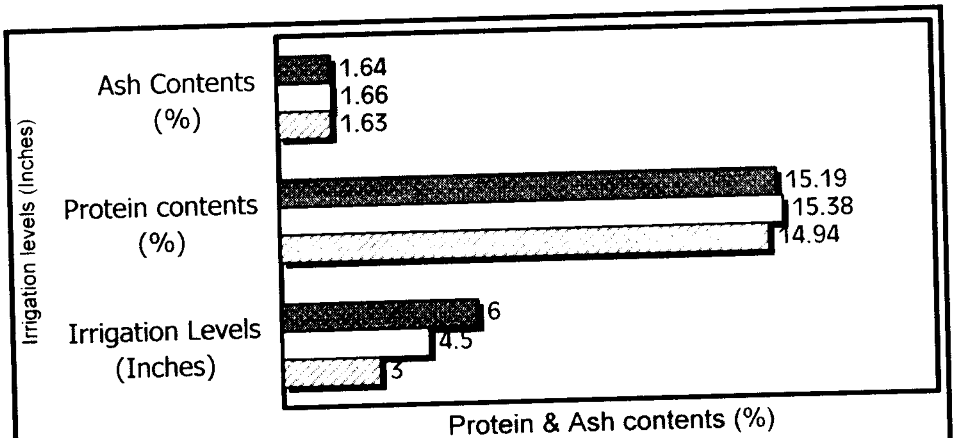

Figure 4. Effect of irrigation frequencies on protein and ash contents (%) (2000-2001)

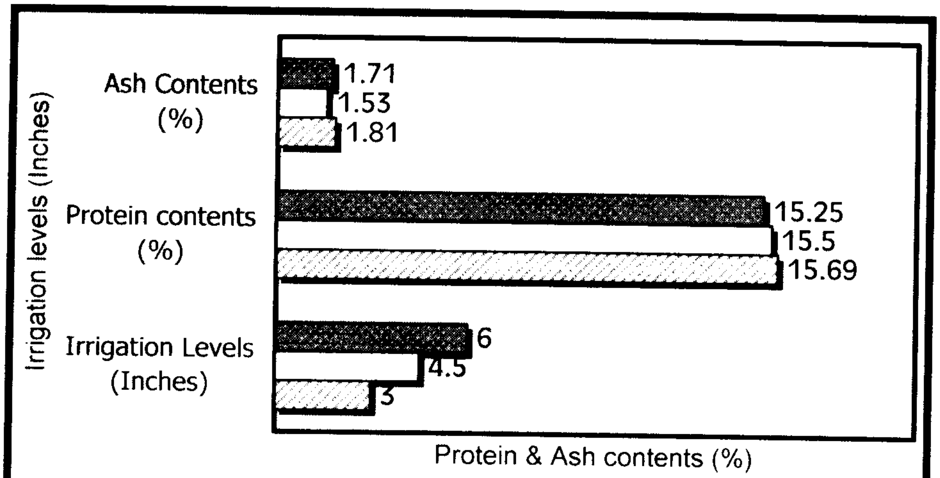

Figure 5. Effect of irrigation frequencies on protein and ash contents (%) (2001-2002)

therefore have a large effect on mineralization rates (Powlson *et al.*, 1986b). Addiscott (1990) suggest that fertilizers could indirectly affect the leaching of nitrate by increasing the amount of readily decomposable organic matter.

CONCLUSIONS

The rate of downward movement of nitrate is affected by the water content of the soil during leaching. This study concludes that under controlled conditions of lysimeters, the leaching of nitrates occurred at higher irrigation application frequencies and nitrates leached from four feet (4') soil column which clearly indicated that due to nitrate leaching, there is a possibility of ground water contamination but the concentration of nitrates are well below the world health organization (WHO) recommended maximum admissible concentration (MAC) for drinking water of 11.3 mg L^{-1} NO_3-N (equivalent to 50 mg NO_3^- L^{-1}).

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