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Soil Physical Health Indices, Soil Organic Carbon, Nitrate Contents and Wheat Growth as Influenced by Irrigation and Nitrogen Rates

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ABSTRACT

This study was conducted for three consecutive years to evaluate the effect of irrigation and nitrogen rates on soil physical health indices, soil organic carbon and nitrate contents in wheat. Three irrigation depths (32.5, 40, 47.5 cm) and three nitrogen levels (0, 125, 160 kg ha^{-1}) were applied. Irrigation depths were kept in the main plots, while nitrogen rates in the sub-plots. The samples were collected from 0-10, 10-25 and 25-40 cm depth for determining the nitrate movement within the soil. The results showed that the plant height, grain yield and straw yield of wheat increased by 12.3%, 23.5% and 40.5%, respectively at nitrogen rate 160 kg ha^{-1} and 47.5 cm irrigation depth than the control. Irrigation and nitrogen application significantly increased SOC contents over control (32.5 cm irrigation depth & 0 kg N ha^{-1}) at both 0-5 cm and 5-10 cm depth. Irrigation and nitrogen caused greater leaching of nitrate than the control at all depths. Findings of the study provide support for further epidemiological investigations and potential strategy for minimizing the nitrate risk especially in sandy region.

Key Words: Nitrogen rate; NO_3 content; SOC; Soil strength; Soil NPK; Irrigation; Wheat yield

INTRODUCTION

Nitrogen is one of the most common nutrients required for plant growth and productivity as it forms an integral part of proteins, nucleic acids and other essential biomolecules (Bockman, 1997). Since the production and wide application of commercial nitrogen (N) fertilizers in agricultural systems, the world has benefited greatly since the productivity reached a level, which seemed impossible several decades ago. Unfortunately, since the last decade, some agricultural production areas started to suffer from environmental problems resulting from inappropriate nitrogen application. Magesan *et al*. (2002) reported that irrigated arid-semiarid areas with shallow water tables, where intensive agriculture is practiced, tend to experience problems of water resource deficiency and groundwater pollution by excessive irrigation and N fertilizer applications. Plants absorb only about 50% of the N applied to the soil and then a large amount of N is lost through leaching (Craswell & Godwin, 1984).

Wheat is a type of shallow-rooted crop and the domain root zone is 0.2 m below the soil surface, which can lead to considerable nitrate loss by leaching under irrigated or high rainfall conditions (Ren *et al.*, 2003; Yu *et al.*, 2003). Increasing fertilizer N inputs to agricultural land beyond crop needs results in gaseous and leaching loss (Spalding & Exner, 1993).

Leaching is the translocation of soluble salts that occurs via a descending flux of water in the soil profile (Kiehl, 1987). In the case of nitrogen, leaching is extremely important because it can noticeably decrease the amount of ammonium and nitrate in the plough layer, and consequently reduce the availability of this nutrient. When excessive, leaching represents a potential groundwater contamination hazard by nitrates (Stark *et al.*, 1983).

Soil drainage is one of the dominant variables that control leaching. The effect of the nitrogen supplied to the crop on groundwater pollution is greater when drainage is a significant water movement whilst, with less drainage, high nitrate contents in soil may result in low leaching losses (Grignani & Zavattaro, 2000; Grignani & Laidlaw, 2002).

The application of fertilizer through flood irrigation water is a common way to provide nutrients for growing crops. However, this method has several shortcomings, including the uneven distribution of nutrients, the high rate of nutrient loss due to leaching, and the occurrence of crop injury (Engelstad, 1985; Playan & Faci, 1997).

So, irrigation and N fertilizers application in excess of crop requirements tend to increase the potential risk of nitrate groundwater, especially for light-textured soils (Ferguson *et al.*, 1991), well-drained soils and intensive production of shallow-rooted crops under irrigated or high

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rainfall conditions, which can lead to considerable nitrate leaching losses (Miburn *et al.*, 1990; Mueller & Helsel, 1996).

This environmental problem is made more acute by the fact that the most ground water recharge take place under agricultural areas and that more than 70% of the drinking water supply comes from ground water. Recent studies have shown that agriculture is directly responsible for more than 50% of the nitrogen that is leached into running waters, because of mineral fertilizer application (Hansen *et al.*, 2000; Owens *et al.*, 2000; Sogbedji *et al.*, 2000).

Nitrate from drinking water accounts for 15-75% of person's exposure to nitrate from environmental sources (Vladeva *et al*., 2000). Nitrate in drinking water is a subject of growing concern world-wide. Ingestion of NO_3^- in drinking water has caused methemoglobinemia in infants (Johnson *et al.*, 1987). High nitrate concentrations are harmful to humans (Keeney, 1982) and increase the risk for eutrophication of estuaries (Weil *et al.*, 1990) and lakes. So, Environmental Protection Agency (EPA) has determined drinking water levels that exceed 10 ppm nitrogen as nitrate to be unsafe for human (Weyer, 1999), while nitrate concentrations more than 11.3 mg NO_3^- N L^{-1}, is recommended limit set by WHO, in drinking water (WHO, 1993).

Pakistan has a marked decline in its per capita water availability from 5600 to 1,000 m3 (Kahlown *et al*., 2001), which resulted in deteriorated quantity and quality of surface and groundwater. The reasons of poor quality of water may be untreated disposal of municipal and Industrial effluents, excessive use of fertilizers and insectcides. In addition, out of the total, 40% of diseases (The Network for Consumer Protection in Pakistan & Action aid Pakistan, 2002) prevalent in the country are water borne and 20 - 40% hospitalizations are due to such water borne diseases.

The reliable assessment of leaching through unsaturated soil is important in tracing the fate of nitrate and other potential pollutants of groundwater (Ganier *et al*., 1993). Information regarding effect of irrigation and N fertilizer application on groundwater pollution due to NO_3 leaching is limited in Pakistan. Some researcher (Ibrahim & Nisar, 1996; Aslam *et al*., 1998) have found that due to less N fertilizer use and the quantity of irrigation water being applied (7.5 cm), there is no chance of groundwater pollution from NO_3 leaching under these climatic conditions.

Considering the wide application of commercial fertilizers and the lack of detailed data in context to nitrate contamination from the whole country, it becomes essential to know the details regarding the nitrate content of the soil at various depths, however the increased use of N fertilizer, increasing cost of fertilizer and public concern about NO_3 pollution of water necessitates for evaluating the effect of irrigation and nitrogen levels on NO_3 movement through soil profiles. Therefore, the present study has the aim of evaluating nitrate levels and SOC content at various depths as affected by N fertilizer application and irrigation depths.

MATERIALS AND METHODS

Field studies were conducted on the Research Farm of the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan (31°26'N; 73°06'E & altitude of 184.4 m), to evaluate the effects of irrigation and nitrogen levels on soil organic carbon, NO_3 movement, selected soil physical properties and the yield of wheat. The existing farming system in this region is predominantly based on rotations, which includes irrigated corn, wheat, cotton, sugarcane, rice, fodder and pulses.

The soil of the study area is a well-drained Hafizabad sandy clay loam (mixed, semi-active, isohyperthermic Typic Calciargids, USDA and contains 530, 210, 260 g kg^{-1} sand, silt and clay, respectively. This soil is generally has low organic matter, N, and P contents to support productive agriculture. Soil physical and chemical characteristics of the study area are presented in Table I. The climate of the region is subtropical to semi-arid with an annual average rainfall of 29.2 mm out of which >70% occurs as heavy shower during June to September. Mean monthly minimum temperature is 13°C in January and maximum temperature is 39°C in July. Average temperature, total rainfall and average relative humidity of research area are presented in Table II.

Three irrigation depths (32.5, 40, 47.5 cm) and three nitrogen levels (0, 125, 160 kg ha^{-1}) were applied depending on treatments. Irrigation depths were kept on the main plots, while nitrogen levels were applied to the sub-plots. Cutthroat flume was used for measuring irrigation depth. Recommended rates of P and K were applied as Triple Super Phosphate (TSP) and Sulphate of Potash (SOP) at planting. Nitrogen was applied in three splits. One third of each nitrogen level was applied at planting, another third at first irrigation and the last third at second irrigation. Hoeing was done to control the weeds. The seeding rate for wheat was 110 kg ha^{-1} and planting was done using a drill machine with an inter-row spacing of 22.5 cm. Sahar variety was planted during three years. The first crop was planted in November, 2008 the second crop in November, 2009 and third crop in November 2010. The experimental layout was a split plot design with the irrigation depth as the main plots and the inorganic nitrogen levels as the sub-plots. Each treatment was replicated thrice. The dimension of the sub-plots was 10 × 10 m. Soil samples were collected randomly from 0.0-0.05, 0.05-0.1, 0.1-0.25 and 0.25-0.4 m depth before planting and at harvest at six different locations on each plot. Samples from each plot were mixed to form a composite. These samples were analyzed for soil organic carbon (SOC) and NO_3-N content during both years. Soil samples were air dried and ground to pass a 2 mm sieve before analyzing for total organic carbon and other soil properties. Total organic carbon was determined by potassium dichromate ($K_2Cr_2O_7$) method (Ryan *et al*., 2001); NO_3-N was measured using a spectrophotometer method (Sims & Jackson, 1971); pH was determined in water (McLean, 1982); electrical conductivity of soil extract was measured by the method developed by Rhoades (1982); cation exchange capacity was measured according to Page *et al*. (1982); and soil texture was determined using Bouyoucos hydrometer method (Moodie *et al*., 2001); soil moisture by gravimetric method, total N by Bremner and Mulvancy (1982); Available P by spectrophotometer (Olsen & Sommers, 1982), Available K by flame photometer (Richards, 1954). Total N was determined by Sulfuric-salicylic acid digestion method (Buresh *et al*., 1982), Total P by spectrophotomer and total K by flame photometer (Chapman & Pratt, 1961). Field measurements that were determined included the soil infiltration rate using Double ring infiltrometer; the soil hydraulic conductivity using a Guelph permeameter; and the soil strength using a Cone penetrometer.

Fertilizer use efficiency (FUE) of N was calculated using the following formula:

$$\text{FUE (kg grains kg}^{-1}\text{ nutrient)} = \frac{\text{Yield with fertilizer–Yield in control}}{\text{Nutrient (kg)}}$$

Water use efficiency (WUE) was calculated using the following formula:

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Water applied (mm)}}$$

Statistical analysis: A split-plot analysis of variance was performed on data collected from this trial and means were separated with Duncan Multiple Range test after significant F-ratio was detected (Steel & Torrie, 1980).

Economic and marginal analysis: The data collected from the studies were used for economic and marginal analysis. Expenditures on different nutrient sources were as follows: N, 0.199 US $ kg^{-1}; P_2O_5, 0.59 US $ kg^{-1}; K_2O, 0.48 US $ kg^{-1}. Sowing expenditures were as follows: ploughing and seed bed preparation, 40.31 US $; seed, 43.07 US $; weedicide, 14.15 US $; harvesting and threshing 95.36 US $ Mg^{-1}. Irrigation (141.0 US $ for I_1; 176.0 US $ for I_2 and 210.7 US $ for I_3. The N was applied @ 0, 125 and 160 kg N ha^{-1}. P and K were applied @ 85:62 kg P_2O_5:K_2O ha^{-1} in all treatments, respectively. Price of the wheat produce is as follows: wheat grain, 265.5 US $ Mg^{-1}; Wheat straw=115.1 US$ Mg^{-1}.

Cost that vary = It is the sum of all the costs (both costs & opportunity cost) that vary for a particular treatment,

Marginal costs = the increase in variable cost, which occurs in changing from one production alternative to another,

Marginal net benefits = the increase in net benefit, which can be obtained by changing from one production alternative to another,

$$\text{Marginal rate of return (MRR)} = \frac{\text{Marginal net benefits}}{\text{Marginal costs}} \times 100 = (\%)$$

RESULTS

The effect of irrigation and nitrogen application on SOC content was statistically significant at 0-5 and 5-10 cm depths. In year-1, maximum SOC content was observed in treatment, where I_3 (47.5 cm) was practiced and it showed 51.1% increase over I_1, (Table III) at 0-5 cm depth. In year - 2, irrigation response was also significant. Maximum SOC content (9.2% more than I_1) was observed with treatment receiving 47.5 cm irrigation depth at 0-10 cm depth. Similar in year-3, I_3 (47.5 cm) irrigation level gave best results (9.8%, more SOC content than I_1) at 0-5 cm depth. Similarly at 5-10 cm depth, I_3 (47.5 cm) irrigation level had 19.1, 15 and 12.2% more SOC content as compared to I_1 (32.5) during 1, 2 and 3 year, respectively. At 10-20 cm depth, maximum SOC content was observed in treatment, where 47.5 cm irrigation depth was applied and it showed 36% increase over 32.5 cm irrigation depth during first year. Similarly during second and third years I_3 (47.5 cm) gave 25 and 23.3% increase in SOC content over I_1. The effect of nitrogen rates was also significant on SOC content at 0-5

Table I: Physical and chemical properties of soil

Soil properties (0-0.04 m)	Values
Sand (%)	53
Silt (%)	21
Clay (%)	26
Textural Class	Sandy Clay Loam
pH	7.5
Electrical Conductivity (d Sm^{-1})	1.35
Bulk Density (Mg m^{-3})	1.45
Hydraulic conductivity (mm h^{-1})	35
Organic carbon contents (%)	0.35
Nitrate Contents (mg kg^{-1})	12.5 mg kg^{-1}

Table II: Average temperature, total rainfall and average relative humidity of research area at meteorological cell of UAF

Year	Temperature (°C)			Total rainfall (mm)	RH (%)
2008-2009	**Maximum**	**Minimum**	**Mean**		
November	27.3	12.2	19.7	0	58.9
December	21.9	09.1	15.5	14.6	68.9
January	19.6	7.3	13.5	13.5	68
February	20.2	08.7	14.4	18.2	73.0
March	27.5	14.0	20.8	14.0	53.5
April	33.5	19.1	26.3	22.9	41.7
2009-2010					
November	25.7	10.8	18.2	0.70	64.7
December	22.1	7	14.5	0	64.4
January	16.2	6	11.1	0.8	82.3
February	22	9.5	15.7	11.9	62.7
March	30.4	16.5	23.5	8.8	57.5
April	38.4	21.4	29.9	1.3	36.8
2010-2011					
November	27.1	10.5	18.8	0	62.3
December	20.8	5.9	13.3	1.0	70.5
January	15.9	4.3	10.1	0	73.4
February	20.1	8.6	14.4	20.6	72.9
March	26.3	13.1	19.7	6.8	59.8
April	32.0	17.1	24.8	20.9	46.9

Data were collected from meteorological cell of UAF

Table III: Effect of irrigation and nitrogen levels on soil organic carbon (%) during 3 years of wheat crop

Treatments		Soil organic carbon (%)											
		0-5 cm				5-10 cm				10-20 cm			
Years	-	**2008**	**2009**	**2010**	**Mean**	**2008**	**2009**	**2010**	**Mean**	**2008**	**2009**	**2010**	**Mean**
	I_1	0.45 c	0.76 b	0.81 b	0.67	0.47 b	0.53 c	0.57 b	0.52	0.25	0.28	0.30	0.28
Irrigation	I_2	0.57 b	0.77 b	0.85 ab	0.73	0.49 b	0.55 b	0.59 b	0.54	0.28	0.31	0.33	0.31
levels (I)	I_3	0.68 a	0.83 a	0.89 a	0.80	0.56 a	0.61 a	0.64 a	0.60	0.34	0.35	0.37	0.35
	N_0	0.43 c	0.71 b	0.75 b	0.63	0.48 b	0.56	0.59 b	0.54	0.29	0.30	0.34	0.31
Nitrogen	N_{125}	0.65 b	0.81 a	0.88 a	0.78	0.51 a	0.56	0.61 b	0.56	0.35	0.37	0.41	0.38
rates (N)	N_{160}	0.72 a	0.84 a	0.92 a	0.83	0.52 a	0.57	0.65 a	0.58	0.38	0.40	0.44	0.41
I * N	$I_1 \times N_0$	0.45 e	0.70 de	0.74 cd	0.63	0.42 cd	0.53 c	0.56	0.50	0.32	0.34	0.37	0.34
	$I_1 \times N_{125}$	0.52 c	0.78 bcd	0.80 bc	0.70	0.45 c	0.52 c	0.54	0.50	0.34	0.37	0.38	0.36
	$I_1 \times N_{160}$	0.56 b	0.80 abc	0.85 b	0.74	0.46 c	0.55 bc	0.59	0.53	0.36	0.39	0.39	0.38
	$I_2 \times N_0$	0.48 d	0.68 e	0.71 d	0.62	0.39 c	0.55 bc	0.58	0.51	0.31	0.34	0.35	0.33
	$I_2 \times N_{125}$	0.57 ab	0.80 abc	0.84 b	0.74	0.42 cd	0.57 ab	0.58	0.52	0.37	0.40	0.42	0.40
	$I_2 \times N_{160}$	0.59 a	0.82 abc	0.88 a	0.76	0.44 c	0.53 c	0.54	0.50	0.39	0.42	0.43	0.41
	$I_3 \times N_0$	0.51 c	0.75 cde	0.76 c	0.67	0.51 b	0.60 ab	0.64	0.58	0.40	0.42	0.44	0.42
	$I_3 \times N_{125}$	0.57 ab	0.85 ab	0.89 a	0.77	0.52 ab	0.60 ab	0.65	0.59	0.42	0.43	0.45	0.43
	$I_3 \times N_{160}$	0.56 b	0.88 a	0.92 a	0.79	0.55 a	0.64 a	0.68	0.62	0.43	0.45	0.46	0.45

Table IV: Effect of irrigation and nitrogen levels on soil NO_3 (mg kg^{-1}) during 3 years of wheat crop

Treatments		Soil NO_3 (mg kg^{-1})											
		0-10 cm				10-25 cm				25-40 cm			
Years	-	**2008**	**2009**	**2010**	**Mean**	**2008**	**2009**	**2010**	**Mean**	**2008**	**2009**	**2010**	**Mean**
	I_1	46.6 a	50.8 a	56.7 a	51.4	43.3 b	46.7 b	51.2 b	47.1	35.5 b	37.7 c	41.4 c	38.2
Irrigation	I_2	39.9 b	46.2 b	51.1 ab	45.7	46.6 a	50.7 a	54.4 a	50.6	54.4 a	59.2 a	64.4 a	59.3
levels (I)	I_3	36.4 c	43.6 b	46.2 b	42.1	45.2 a	48.1 ab	51.7 a	48.3	52.4 a	56.5 b	58.7 b	55.9
	N_0	31.2 b	34.3 c	37.7 b	34.4	32.2 c	36.1 c	39.8 c	36.0	34.5 c	37.3 c	39.3 c	37.0
Nitrogen rates	N_{125}	46.2 ab	49.8 b	53.4 ab	49.8	46.9 b	52.4 b	55.6 b	51.6	49.9 b	54.0 b	57.7 b	53.9
(N)	N_{160}	48.8 a	56.4 a	59.7 a	55.0	51.8 a	57.0 a	60.1 a	56.3	58.5 a	62.0 a	65.5 a	62.0
I * N	$I_1 \times N_0$	33.3 d	36.7 e	41.1 d	37.0	30.1 e	35.3 c	37.7 e	34.4	24.2 f	28.7 e	34.2 d	29.0
	$I_1 \times N_{125}$	49.0 ab	54.3 bc	59.9 ab	54.4	47.4 b	51.6 b	55.6 bc	51.5	36.6 e	39.6 d	43.5 c	39.9
	$I_1 \times N_{160}$	55.4 a	61.5 a	64.7 a	60.5	48.8 b	53.4 b	59.9 b	54.0	39.7 d	44.9 d	46.5 c	43.7
	$I_2 \times N_0$	32.3 d	34.1 e	36.6 e	34.3	33.4 d	36.6 c	37.2 e	35.7	35.5 e	40.7 d	42.2 c	39.5
	$I_2 \times N_{125}$	42.2 c	48.9 cd	53.3 b	48.1	49.9 b	54.6 ab	57.7 b	54.1	62.2 ab	64.5 b	68.5 ab	65.1
	$I_2 \times N_{160}$	46.6 b	55.8 ab	58.5 b	53.6	56.6 a	61.2 a	68.7 a	62.2	68.8 a	72.5 a	76.5 a	72.6
	$I_3 \times N_0$	28.8 d	32.3 e	34.4 e	31.8	32.2 d	36.5 c	41.1 d	36.6	40.4 d	42.5 d	44.7 c	42.5
	$I_3 \times N_{125}$	42.2 c	46.5 d	48.8 c	45.8	46.6 bc	51.1 b	53.3 c	50.3	55.2 c	58.2 c	63.3 b	58.9
	$I_3 \times N_{160}$	46.6 b	52.1 bcd	54.4 b	51.0	49.5 b	56.7 ab	58.4 b	54.9	62.2 ab	68.8 ab	76.6 a	69.2

Table V: Effect of irrigation and nitrogen levels on soil physical indicators during 3 years of wheat crop

Treatments		Soil physical indicators											
		Infiltration rate (mm h^{-1})				Hydraulic conductivity (mm h^{-1})				Soil strength (kPa)			
Years	-	**2008**	**2009**	**2010**	**Mean**	**2008**	**2009**	**2010**	**Mean**	**2008**	**2009**	**2010**	**Mean**
	I_1	18.9 c	24.6 c	22.0 c	21.8	76.7	78.0	78.2	77.6	640.5 a	623.7 a	606.2 a	623.5
Irrigation	I_2	29.1 b	36.0 b	32.6 b	32.5	77.1	82.6	85.0	81.6	591.0 b	593.7 b	572.2 b	585.6
levels (I)	I_3	35.6 a	43.3 a	39.6 a	39.5	74.0	80.0	82.0	78.7	601.9 b	579.2 b	562.2 b	581.1
	N_0	23.6 c	32.0 b	28.1 b	27.9	63.0 b	66.3 b	68.2 b	65.8	588.4	559.7 b	544.9 b	564.3
Nitrogen rates	N_{125}	28.8 b	34.7 ab	31.8 b	31.7	79.9 a	84.6 a	87.0 a	83.8	617.7	612.5 a	590.6 a	606.9
(N)	N_{160}	31.1 a	37.2 a	34.3 a	34.2	84.9 a	89.7 a	88.7 a	87.8	627.7	624.4 a	605.1 a	619.1
I * N	$I_1 \times N_0$	15.4 e	19.4 g	22.2 d	19.0	56.4 c	58.3 c	60.0 c	58.2	625.5 a	605.9 a	593.3 b	608.2
	$I_1 \times N_{125}$	19.8 de	23.4 f	25.5 d	22.9	84.4 a	88.2a	90.8 a	87.8	652.2 a	635.2 a	615.5 a	634.3
	$I_1 \times N_{160}$	21.4 d	25.1 e	26.2 d	24.2	89.4 a	87.5a	84.0 ab	87.0	644.0 a	630.0 a	609.9 a	628.0
	$I_2 \times N_0$	24.9 c	29.5 d	33.8 c	29.4	72.4 ab	75.9 ab	78.1 ab	75.5	565.5 c	525.4 c	505.9 c	532.3
	$I_2 \times N_{125}$	30.1 b	32.7 c	35.5 b	32.8	76.6 ab	82.4ab	84.8 ab	81.3	595.4 b	617.9 a	590.9 b	601.4
	$I_2 \times N_{160}$	32.2 b	35.9 b	38.8 b	35.6	82.5a	89.5a	92.1 a	88.0	612.2 ab	637.8 a	620.0 a	623.3
	$I_3 \times N_0$	30.5 b	37.5 b	40.1 a	36.0	60.2 c	64.8bc	66.7 c	63.9	574.4 c	547.8 bc	535.7 c	552.6
	$I_3 \times N_{125}$	36.6 a	39.6 a	43.3 a	39.8	78.8 ab	83.2ab	85.6 ab	82.5	605.5 ab	584.6 ab	565.4 bc	585.2
	$I_3 \times N_{160}$	39.7 a	43.1 a	46.6 a	43.1	83 a	92.1 a	90 a	88.5	625.8 a	605.4 ab	585.5 b	605.6

Means for treatments within columns for each experiment followed by the same letter are not significantly different at α=0.05

I_1 = 32.5cm of water, I_2 = 40 cm of water, I_3 = 47.5 cm of water, N_0 = Nitrogen @ 0 kg ha^{-1}, N_{125} = Nitrogen @ 125 kg ha^{-1}, N_{160} = Nitrogen @ 160 kg ha^{-1}

and 5-10 cm depths (Table III). Mean maximum value (0.72%) was observed in N_{160}, followed by N_{130} (0.65%) and minimum in N_0 (0.43%) at 0-5 cm depth during first year. Similarly, mean maximum value (0.84%) was observed in N_{160}, followed by N_{130} (0.81%) and minimum in N_0 (0.71%) at 0-5 cm depth during the second year. In year-3, nitrogen

Table VI: Effect of irrigation and nitrogen levels on yield and yield contributing factors during 3 years of wheat crop

Treatments		Plant growth parameters															
		Plant height (cm)				Spike length (cm)				Grain yield (t ha^{-1})				Straw yield (t ha^{-1})			
Years	-	2008	2009	2010	Mean	2008	2009	2010	Mean	2008	2009	2010	Mean	2008	2009	2010	Mean
	I_1	79.5 b	82.1 c	88.6 b	83.4	8.55c	9.33b	9.42b	9.42	2.90b	3.08c	3.60b	3.19	4.61c	4.66c	4.72c	4.66
Irrigation	I_2	82.2 b	86.4 b	90.9ab	86.5	9.15b	9.26b	9.32b	9.32	3.20b	3.54a	3.80a	3.51	4.90b	5.22b	5.42b	5.18
levels (I)	I_3	86.6 a	89.2 a	92.4 a	89.4	10.5a	10.4a	10.5a	10.5	3.10a	3.27b	3.90a	3.42	5.31a	5.75a	6.22a	5.76
	N_0	78.8 b	82.5 b	87.0 b	82.8	8.60c	8.88c	9.4b	9.40	2.86c	2.98c	3.15b	3.00	4.47c	4.50c	4.54b	4.50
Nitrogen	N_{125}	82.2 b	84.7 b	88.9 b	85.3	9.60b	9.81b	10.1a	10.1	3.15b	3.34b	3.52a	3.34	5.01b	5.20b	5.45b	5.22
rates (N)	N_{160}	89.9 a	93.5 a	96.1 a	93.2	10.3a	10.5a	10.6a	10.6	3.40a	3.56a	3.65a	3.54	5.35a	5.92a	6.25a	5.84
I * N	I_1 x N_0	84.8e	88.2c	89.2c	87.4	8.6d	8.8c	8.9d	8.77	2.77e	2.88d	3.10d	2.92	3.90e	4.02e	4.15e	4.02
	I_1 x N_{125}	86.6d	90.0b	91.2b	89.3	9.4c	9.7b	9.8b	9.63	3.11c	3.24c	3.41c	3.25	4.24d	4.37d	4.67c	4.43
	I_1 x N_{160}	94.4b	98.2a	99.2a	97.3	10.0b	10.3b	10.5b	10.27	3.35b	3.48b	3.54b	3.46	4.95b	5.10b	5.03b	5.03
	I_2 x N_0	87.3c	90.8b	91.3b	89.8	8.6d	8.8c	9.1c	8.83	3.18c	3.31c	3.35c	3.28	4.30d	4.43d	4.48d	4.40
	I_2 x N_{125}	89.0c	92.6b	94.4a	92.0	9.4c	9.7b	9.9b	9.67	3.58b	3.72b	3.84b	3.71	4.70c	4.84bc	4.98c	4.84
	I_2 x N_{160}	96.4a	98.3a	99.2a	98.0	9.8b	10.1b	10.4b	10.10	3.85a	4.01a	4.30a	4.05	5.10b	5.25b	5.24b	5.20
	I_3 x N_0	89.0c	92.5b	94.5a	92.0	9.5c	9.8b	10.2b	9.83	2.99d	3.11c	3.50b	3.20	4.55c	4.69c	4.77c	4.67
	I_3x N_{125}	91.0b	94.6a	96.2a	93.9	10.5b	10.8b	10.9b	10.73	3.32b	3.45b	3.60b	3.46	5.15b	5.30b	5.37b	5.27
	I_3 x N_{160}	97.4a	98.5a	98.8a	98.2	11.2a	11.5a	11.6a	11.43	3.49b	3.63b	3.75b	3.62	5.50a	5.67a	5.78a	5.65

Table VII: Effect of irrigation and nitrogen levels on nutrients uptake and soil NPK during 3 years of wheat crop

Treatments		Nutrients uptake			Soil NPK at the end of experiment		
	-	N uptake	P uptake	K uptake	N (g kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})
Irrigation levels (I)	I_1	90.1 b	26.1 c	115.0 b	0.41	13.1 b	131.1
	I_2	93.8 b	28.5 b	117.7 b	0.45	14.26 a	128.1
	I_3	104.4 a	31.0 a	123.1 a	0.50	14.54 a	130.8
	N_0	95.0 b	26.9 b	107.4 b	0.39 c	12.25 c	116.8 c
Nitrogen rates (N)	N_{125}	96.0 ab	28.8 a	122.3 a	0.45 b	14.43 b	131.2 b
	N_{160}	97.4 a	29.8 a	126.2 a	0.51 a	15.26 a	142.1 a
I * N	I_1 x N_0	88.2 c	24.6 e	104.9 d	0.370 c	10.14 f	113.8 c
	I_1 x N_{125}	88.5 c	26.2 de	117.9 b	0.39 c	14.28 cd	136.8 ab
	I_1 x N_{160}	93.6 bc	27.6 cde	122.4 ab	0.474 b	14.96 abc	142.8 a
	I_2 x N_0	94.0 bc	26.8 cde	105.1 d	0.358 c	12.82 e	117.7 bc
	I_2 x N_{125}	97.6 abc	29.1 bcd	122.1 ab	0.475 b	14.47 bcd	127.9 abc
	I_2 x N_{160}	89.7 c	29.6 abc	126.0 ab	0.51 ab	15.50 a	138.8 a
	I_3 x N_0	102.6 ab	29.4 abc	112.3 c	0.464 b	13.79 d	118.9 bc
	I_3x N_{125}	101.8 ab	31.1 ab	126.9 ab	0.483 b	14.53 abcd	129.0 abc
	I_3 x N_{160}	108.8 a	32.4 a	130.2 a	0.552 a	15.31 ab	144.6 a

Table VIII: Effect of irrigation and nitrogen levels on fertilizer and water use efficiency during 3 years of wheat crop

Treatments		Water use efficiency (kg ha^{-1} mm^{-1})			Fertilizer use efficiency (kg grains kg^{-1} nutrient)		
Year	-	2008	2009	2010	2008	2009	2010
	I_1	9.41 a	9.74 a	10.3 a	2.46 b	2.80 c	3.57 c
Irrigation levels (I)	I_2	8.84 b	9.21 b	9.57 b	4.83 a	5.58 a	6.51 a
	I_3	6.87 c	7.15 c	7.61 c	3.23 b	3.86 b	4.49 b
	N_0	7.51 c	7.89 c	8.43 c	0.0	0.00	0.00
Nitrogen rates (N)	N_{125}	8.52 b	8.84 b	9.22 b	4.95 a	5.92 b	7.05 a
	N160	9.10 a	9.36 a	9.84 a	5.57 a	6.32 a	7.53 a
I * N	I_1 x N_0	8.30 bcd	8.86 cd	9.54 b	0.00	0.00	0.00
	I_1 x N_{125}	9.64 ab	9.97 ab	10.4 a	3.33 c	4.15 c	5.46 c
	I_1 x N_{160}	10.3 a	10.4 a	10.8 a	4.06 c	4.25 c	5.25 c
	I_2 x N_0	7.95 cde	8.28 de	8.38 c	0.00	0.00	0.00
	I_2 x N_{125}	8.95 bc	9.30 bc	9.60 b	6.77 ab	7.85 ab	8.77 ab
	I_2 x N_{160}	9.63 ab	10.0 a	10.7 a	7.74 a	8.89 a	10.7 a
	I_3 x N_0	6.29 f	6.53 g	7.37 d	0.00	0.00	0.00
	I_3x N_{125}	6.99 ef	7.26 fg	7.58 d	4.77 bc	5.77 bc	6.92 bc
	I_3 x N_{160}	7.35 def	7.64 ef	7.89 cd	4.93 bc	5.81 bc	6.56 bc

Means for treatments within columns for each experiment followed by the same letter are not significantly different at α=0.05

I_1 = 32.5cm of water, I_2 = 40 cm of water, I_3 = 47.5 cm of water, N_0 = Nitrogen @ 0 kg ha^{-1}, N_{125} = Nitrogen @ 125 kg ha^{-1}, N_{160} = Nitrogen @ 160 kg ha^{-1}

application @ 160 kg ha^{-1} gave best results (22.6%, more SOC content than control) at 0-5 cm depth. Similar results were found at 5-10 and 10-20 cm depths in case of nitrogen rate during all three years. The interactive effect of irrigation and nitrogen rates was also significant (Table III), the mean maximum value of SOC content (0.56%) was observed in I_3

(47.5 cm) in combination with N_{160} and minimum (0.45%) in I_1 x N_0 combination during first year at 0-5 cm depth. Similarly, maximum value of SOC content was observed with treatment combination I_3 x N_{160} (0.88%) and minimum in I_2 x N_0 treatment (0.68%) at 0-5 cm depth during second year. In year-3, I_3 (47.5 cm) along with nitrogen application @ 160 kg ha^{-1} gave best results (24.3%, more SOC content than I_1 x N_0) at 0-5 cm depth. Similar trend was noted at 0-10 and 10-20 cm depths.

Result from three years study revealed that both irrigation and nitrogen rates affected significantly NO_3 content at 0-10 cm, 10-25 cm and 25-40 cm depth. In year-1, a maximum increase of 28% was observed in NO_3 content, over I_3 (47.5 cm) in treatments, where 32.5 cm irrigation depth was applied (Table IV) at 0-10 cm depth. In year-2, I_1 (32.5 cm) irrigation level gave best results (16.5%, more NO_3 content than I_3) at 0-10 cm depth. In year -3, irrigation response was also significant. Maximum NO_3 content (22.7% more than I_3) was observed with treatment receiving 32.5 cm irrigation depth at 0-10 cm depth. At 10-25 cm depth, I_2 (40 cm) irrigation level had 7.6, 8.5 and 6.2% more NO_3 content as compared to I_1 (32.5 cm) during 1, 2 and 3 year, respectively. At 25-40 cm depth, maximum NO_3 content was observed in treatment, where 47.5 cm irrigation depth was applied and it showed 47.6% increase over 32.5 cm irrigation depth during first year. Similarly during second and third years I_3 (47.5 cm) gave 49.8 and 41.7% increase in NO_3 content over I_1. The effect of nitrogen rates was also significant at all soil depths (Table IV). Mean maximum value was observed in N_{300} (48.8 mg kg^{-1}), followed by N_{130} (46.2 mg kg^{-1}) and minimum in N_0 (31.2 mg kg^{-1}) at 0-10 cm depth during first year. Similarly, mean maximum value was observed in N_{160} (56.4 mg kg^{-1}), followed by N_{130} (49.8 mg kg^{-1}) and minimum in N_0 (34.3 mg kg^{-1}) at 0-10 cm depth during second year. Similarly during third year N_{160} (160 kg ha^{-1}) gave 58.3% increase in NO_3 content over N_0. Similar results were noted at 10-25 and 25-40 cm depths in case of nitrogen application during all three the years. The interactive effect of irrigation and nitrogen rates was also significant (Table IV), the mean maximum value of NO_3 content was observed in I_1 (55.4 mg kg^{-1}) in combination with N_{160} and minimum (28.8 mg kg^{-1}) in I_3 x N_0 combination during first year at 0-10 cm depth. Similarly, maximum value of NO_3 content was observed with treatment combination I_1 x N_{160} (61.5 mg kg^{-1}) and minimum in I_3 x N_0 treatment (32.3 mg kg^{-1}) at 0-10 cm depth during second year. Similar results were noted during third year. At 10-25 and 25-40 cm depths, more NO_3 content was found in heavy irrigation along with higher N fertilizer.

The data regarding the effect of irrigation and nitrogen rates on soil physical indicators indicated that both irrigation and nitrogen rates had significant effect on soil physical indicators. The effect of irrigation on infiltration rate was statistically significant. In year-1, maximum infiltration rate was observed in treatment, where 47.5 cm irrigation depth was applied and it showed 88.3% increase over I_1 (32.5 cm) (Table V). In year -2 and 3 irrigation response was also significant. Maximum infiltration rate [76% & 80% more than I_1 (32.5)] was observed with treatment receiving 47.5 cm irrigation depth respectively. Different nitrogen treatments significantly affected infiltration rate during three years of study. The highest infiltration rate of 31.1 mm h^{-1} was obtained for the N_{160} treatment and the lowest (23.6 mm h^{-1}) for the N_0 treatment (Table V) during fist year. Similarly during second and third year, the highest infiltration rate of 37.2 and 34.2 mm h^{-1} was obtained for the N_{160} treatment and the lowest (32.0 & 28.1 mm h^{-1}) for the N_0 treatment. As regard field saturated hydraulic conductivity, statistically non-significant response was observed with increasing irrigation depth during three years of study (Table V). A significant effect of different nitrogen rates on field saturated hydraulic conductivity was also found during the study years. The highest field saturated hydraulic conductivity of 84.9 mm h^{-1} was obtained for N_{160} treatment and the lowest (63.0 mm h^{-1}) for the N treatment (Table V) during 1-year. Similar results were found in case of second and third year. Data showed that higher irrigation depth reduced the soil strength significantly (Table V). During three, minimum soil strength [6.0, 7.1 & 7.2% less than I_1 (32.5 cm), during year-1, 2 & 3, respectively] were observed in case of treatments, where 47.5 cm irrigation depth was applied.

Maximum plant height (86.6 cm) was recorded for 47.5 cm irrigation depth, which on an average was 5.3 and 8.9% higher than 40 and 32.5 cm irrigation depths, respectively during first year (Table VI). Similar during second year, maximum plant height (89.2 cm) was recorded for 47.5 cm irrigation depth, which on an average was 3.2 and 8.6% higher than 40 and 32.5 cm irrigation depths, respectively. During 3-year, I_3 (47.5 cm) irrigation level had 1.6 and 4.2% more plant height compared to 40 and 32.5 cm irrigation depths, respectively. Tallest plants (89.9 cm) were produced when crop was fertilized with N @ 160 kg ha^{-1} (Table VI) during 1-year. During second year, N_{160} treatment resulted in 10.3 and 13.3% more plant height compared to N_{130} and N_0 treatments. Similarly in year-3, nitrogen application @ 160 kg ha^{-1} gave best results (10.4%, more plant height than control). The effect of irrigation on spike length was statistically significant. In year-1, maximum spike length was observed in treatment, where 47.5 cm irrigation depth was applied and it showed 22.8% increase over I_1 (32.5 cm) (Table VI). In year -2, irrigation response was also significant. Maximum spike length (11.4% more than control) was observed with treatment receiving 47.5 cm irrigation depth. During 3-year, I_3 (47.5 cm) irrigation level had 12.6 and 11.4% more spike length compared to 40 and 32.5 cm irrigation depths, respectively. Different nitrogen treatments significantly affected spike length during three years of study. The highest spike length of 10.3 cm was obtained for the N_{160} treatment and the lowest (8.6 cm) for the N_0 treatment (Table VI) during fist year. Similarly during second year, the highest spike length

Table IX: Economic analysis for wheat (2009-2010)

Irrigation levels	Nitrogen rates (kg ha^{-1})	Grain yield (Mg ha^{-1})	Straw yield (Mg ha^{-1})	Variable cost (US $ ha^{-1})	Permanent cost (US. $ ha^{-1})	Total cost (US $ ha^{-1})	Gross income (US $ ha^{-1})	Net return (US $ ha^{-1})	Net field benefits (US $ ha^{-1})	Benefit cost ratio
I_1	N_0	2.92	4.02	141.0	786.5	927.5	1236.5	309	1095.5	4.00
	N_{125}	3.25	4.43	158.3	786.5	944.8	1371.2	426.4	1212.9	3.21
	N_{160}	3.46	5.03	175.7	786.5	962.2	1495.9	533.7	1320.2	2.80
I_2	N_0	3.28	4.40	175.9	786.5	962.4	1375.7	413.3	1199.8	3.32
	N_{125}	3.71	4.84	193.2	786.5	979.7	1540.3	560.6	1347.1	2.74
	N_{160}	4.05	5.20	210.5	786.5	997	1671.8	674.8	1461.3	2.47
I_3	N_0	3.2	4.60	210.7	786.5	997.2	1377.5	380.3	1166.8	3.62
	N_{125}	3.46	5.27	228.0	786.5	1014.5	1523.6	509.1	1295.6	2.99
	N_{160}	3.62	5.65	245.3	786.5	1031.8	1609.7	577.9	1364.4	2.78

Table X: Dominance and Marginal analysis for wheat (2009-2010)

Irrigation levels	Nitrogen rates (kg ha^{-1})	Variable cost (US .$ ha^{-1})	Net field benefits (US $ ha^{-1})	Marginal cost that vary	Marginal net field benefits	Marginal rate of return	Dominated treatments
I_1	N_0	141.0	1095.5				
I_1	N_{125}	158.3	1212.9	17.3	117.4	6.786127	
I_1	N_{160}	175.7	1320.2	17.3	107.3	6.202312	
I_2	N_0	175.9	1199.8	-	-	-	D
I_2	N_{125}	193.2	1347.1	17.3	147.3	8.514451	
I_2	N_{160}	210.5	1461.3	17.3	114.2	6.601156	
I_3	N_0	210.7	1166.8	-	-	-	D
I_3	N_{125}	228.0	1295.6	17.3	128.8	7.445087	
I_3	N_{160}	245.3	1364.4	17.3	68.8	3.976879	

Means for treatments within columns for each experiment followed by the same letter are not significantly different at α=0.05.
I_1 = 32.5cm of water, I_2 = 40 cm of water, I_3 = 47.5 cm of water, N_0 = Nitrogen @ 0 kg ha^{-1}, N_{125} = Nitrogen @ 125 kg ha^{-1}, N_{160} = Nitrogen @ 160 kg ha^{-1}

of 10.5 cm was obtained for the N_{160} treatment and the lowest (8.88 cm) for the N_0 treatment. During 3-year, N_{160} (160 kg ha^{-1}) treatment had 4.9 and 12.7% more spike length compared to N_{125} and N_0 treatments, respectively. Data revealed that grain yield and straw yield were significantly ($P \leq 0.05$) increased by the application of irrigation and nitrogen fertilizer, over the control (Table VI). In year-1, -2 and -3 maximum grain yield and straw yield were observed in treatments, 47.5 cm irrigation depth was applied along with N_{160}. This treatment increased the grain yield by 25.9, 26 and 20.9%; straw yield by 41.9, 41 and 39.2% more than control.

The results of our study revealed that the application of nitrogen fertilizer increased the NPK uptake by wheat crop, over control along with increasing irrigation depth. On average, maximum N uptake (23.3% more than control) was observed in case of treatment receiving 47.5 cm irrigation depth along with N_{160}. This study demonstrated a maximum increase of P, 31.7% and K, 24.1%, respectively over control, in case of treatments, where 47.5 cm irrigation depth was applied along with N_{160} (Table VII). It was revealed from the data that soil N, P and K were significantly ($P \leq 0.05$) increased by the application irrigation and nitrogen fertilizer over the control (Table VII). Maximum soil N, P and K were observed in treatments, where 47.5 cm irrigation depth was applied along with N_{160}. This treatment increased the soil N by 49.1%; soil P by 50.9% and soil K by 27% more than control (I_1 x N_0) at the end of experiment.

There were significant differences among treatments in case of water use efficiency (Table VIII). Water use efficiency was improved with increasing N rate but decreased with increasing irrigation depth; and their combined use was also significant during all three years. The results of our study revealed that the application of nitrogen fertilizer increased the fertilizer use efficiency, over control along with increasing irrigation depth (Table VIII). The maximum FUE (7.74) was observed in case of treatment receiving 40 cm irrigation depth along with N_{160} during first year. Similar results were noted during 2nd and 3rd years.

Data regarding economic analysis of wheat yield during 2009-2010 indicate that the maximum net field benefit of 1461.3 US $ ha^{-1} was achieved from treatment combination $I_2 \times N_{160}$ followed by $I_3 \times N_{160}$ having 1364.4 US $ ha^{-1} and the lowest (1095.5 US $ ha^{-1}) in the case of $I_1 \times N_0$ treatment (Table IX). Dominance and marginal analysis indicate that marginal rate of return was maximum from the treatment combination $I_2 \times N_{125}$ followed by $I_3 \times N_{125}$ and $I_1 \times N_{125}$, while all other treatment combinations were un-economical due to higher input cost and low returns (Table X).

DISCUSSION

This study demonstrated the effectiveness of different levels of irrigation and nitrogen fertilizer for improving growth, yield and nutrients (N, P & K) uptake of wheat, soil organic carbon and nitrate content. Our results indicated that best results were obtained with application of 160 kg N ha^{-1}

combined with 47.5 cm irrigation depth. The interactive effect of irrigation and nitrogen rates was also significant, the mean maximum value of SOC content (0.56 %) was observed in I_3 (47.5 cm) in combination with N_{160} and minimum (0.45%) in I_1 x N_0 combination during first year at 0-5 cm depth. Similarly, maximum value of SOC content was observed with treatment combination I_3 x N_{160} (0.88%) and minimum in I_2 x N_0 treatment (0.68%) at 0-5 cm depth during second year. In year-3, I_3 (47.5 cm) along with nitrogen application @ 160 kg ha^{-1} gave best results (24.3%, more SOC content than I_1 x N_0) at 0-5 cm depth. Similar trend was noted at 0-10 and 10-20 cm depths. These results are in accordance with Rasool *et al.* (2008) who concluded that SOC concentration increased up to 21% by balance application of chemical fertilizer ($N_{100}P_{50}K_{50}$). Similar by Sharma *et al*. (2002) reported increase in SOC due to inorganic fertilization. This was due to C addition through the roots and crop residues (Prakash *et al*., 2002) over the control plots. Russell *et al*. (2005) also reported significant effects of N fertilization rate on SOC pool in the 0-15 cm depth. In an other study, Jagadamma *et al*. (2007) observed SOC pool in 0-30 cm depth that ranged from 68.4 Mg ha^{-1} for N_0 to 75.8 Mg ha^{-1} for 280 (N_4) kg N ha^{-1}.

The results of our study revealed that increasing the nitrogen rates also increased the NO_3 content combined with 47.5 cm irrigation depth. Craswell and Godwin (1984) also reported that plants absorb only about 50% of the N applied to the soil and then a large amount of N is lost through leaching. These results are in line with El-Garawany *et al.* (2005) who reported that concentrations of NO_3^- were 3.9, 22.0, 26.6 and 45.2 mg kg^{-1} for virgin soil, FYM, urea and FYM + urea soils, respectively. The highest value of NO_3^- was recorded at 20-30 cm depth in case of urea application alone. Losses of NO_3-N increased as the rate of N applied increased. At all depths studied higher statistical, significant differences were found for 200 N compared to 100 N and 0 N, and for 100 N compared to 0 N. These results are reported by Lee and Jose (2005).

Irrigation and nitrogen fertilizer also improved soil physical properties. Rahman *et al.* (2000) also reported that higher frequency of irrigation had remarkably reduced soil strength in the surface layer, but N application could not create any impact on it. Lal and Shukla (2004) also found that soil moisture content is important to soil strength; as soil moisture content increases, soil strength decreases through a reduction in cohesion.

The results of our study revealed that increasing the nitrogen rates also increased growth, yield the NPK uptake by wheat crop, over control (I_1 x N_0). Increase in plant height at high fertilizer level might be due to proper nutrition availability, which resulted in increase in vegetative growth of the plants. Similar result were recorded by Maqsood *et al.* (2000) concluded that application of nitrogen at the rate of 125 kg ha^{-1} produced significantly taller plants (97.6 cm) than 100 and 75 kg N ha^{-1}, yet it did not differ significantly from treatment 150 kg N ha^{-1} (97.1 cm). Syleus-Bradley *et al.* (1990) also reported that plant height of wheat increased significantly and linearly with increased nitrogen application. Maqsood *et al*. (1999) also observed maximum spike length (11.0 cm) in case of 140 kg N ha^{-1}. These results were in accordance with Bazitov (2000) who concluded that grain yield increased significantly with increase in nitrogen application due to more number of tillers $plant^{-1}$, longer spikes, more number of spikelets $spike^{-1}$ and greater number of fertile florets resulted in maximum number of grain filled thus, all collectively resulted into increased grains yields ha^{-1}. Similar, Singh and Sharma (2001) also reported that grain yield and yield-attributing parameters (number of productive tillers & length of spikes) increased significantly with increasing N levels up to 150 kg ha^{-1}. Our results are also in line with Kumbhar *et al.* (2007) who found that increase in levels of fertilizer at 150-50 NP kg ha^{-1} progressively increased grain yield (3198.2 kg ha^{-1}). The increase in straw yield with added nitrogen to soil was also reported by (Allam, 2003). Niaz *et al.* (2004) also found that higher irrigation levels significantly affected the straw yield. The result substantiates the findings of Rodrigues *et al.* (2001) who reported that nitrogen fertilization caused significant increases in both the content and uptake of nitrogen of grain and also of straw. Such increment may be attributed due to the increase in the nitrogen concentration in soil solution and consequently increasing its uptake by plants. The same trend was observed by Tejada and Gonzalez (2003). El-Sherbieny *et al.* (1999) also stated that increasing the rate of added nitrogen increased the total contents of nitrogen, phosphorus and potassium of wheat. Sądej and Przekwas (2008) also observed increase in total nitrogen content with increasing N rates in the uppermost soil layer and soil nitrogen content decreased with soil depth. Raza *et al.* (2005) reported that recommended dose of NPK gave better FUE values as compared to half or double doses. Similarly, Deju and Jingwen (1993) recorded a WUE of 10 kg ha^{-1} mm^{-1} for wheat grain. Daniels and Scott (1991) also reported an average WUE of 9.66 kg ha^{-1} mm^{-1} of water.

CONCLUSION

Irrigation and nitrogen amendments had exerted variable effects on NO_3 leaching, soil physical quality indicators and wheat yield. The NO_3 leaching was consistently increased by increasing irrigation depth and it is increasing with increase in nitrogen rates. Soil organic carbon (SOC) was also increased with increase in irrigation depth and nitrogen rates. The economic determines the ultimate feasibility and practicability of any agriculture practice. The results revealed that irrigation (40 cm) irrigation depth along with nitrogen @ 125 kg ha^{-1} was most economical treatment combination. This study has led to the apprehension that support efforts for the awareness and education of the communities regarding the water quality testing for nitrate contamination, health hazards and ways to avoid drinking water pollution as well as detailed monitoring and alleviation activities are highly recommended for affected areas to safeguard the natives from the possible potential nitrate toxicities. Long-term studies may be required to detect combine effect of irrigation and nitrogen levels on soil physical quality indicators and soil fertility for economic crop production.

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