

Environmental Impacts of Wastewater Irrigation on Yield and Protein Content of Wheat

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ABSTRACT

Looking to present scenario of withdrawals of surface water and ground water, the futuristic demand of water resources for irrigation will be highly critical. The scarce surface water resources cause decrease in annual intensity of irrigation and thereby poor economy due to insufficient agricultural production. The sewage water as irrigation water can be explored in arid and semi-arid regions as alternate water resource. The safe utilization of treated wastewater does not only conserve fresh water resources but also helps in increasing agricultural production. In this direction, experiments focusing reuse of sewage effluent in irrigation of wheat were conducted at Campus of Nirma University, Ahmedabad. The experiment involved various treatments according to application of sewage water, ground water & surface water in different blending ratios and various treatments according to application of nitrogenous fertilizer to soils. The yield and protein content of wheat are analyzed under said treatments and envisaged in the paper. It is observed that main effects of Irrigation Treatment on Wheat yield are significant whereas main effects of Fertilizer Treatment on the same are non-significant at the 0.05 significance level. The main effects of Irrigation Treatment as well as Fertilizer Treatment on Protein content are non-significant at the 0.05 significance level.

Keywords: Sewage water, ground water, surface water, yield, protein content

Journal of Economic Literature (JEL) Classification: Q51

Mathematics Subject Classification Number: 91B76

1. INTRODUCTION

Quantitative as well as qualitative water resources are national assets. Poor water availability becomes a severe constraint in food production, economic development and protection of natural systems. On the contrary, the generation of large quantum of wastewater favours sewage farming practice in a big way looking to high nutritive value of sewage. Under these perceptions, sewage water can be promoted as alternative source for irrigation as it may become more important source of organic matter and nutrient supply for crop production. With this objective, research work was carried out to determine environmental impacts that include qualitative and quantitative aspects of agricultural produce.

2. EXPERIMENTAL DESIGN

With a view to conserve surface & ground water resources, promote safe agricultural reuse of sewage water and study the environmental impacts of waste water irrigation on wheat, it was decided to conduct experiments on wheat crop at Campus of Nirma University, Ahmedabad.

With a view to analyse environmental impacts of irrigation for Wheat by blending sewage water with ground water and surface water, the experiments were designed with seven irrigation treatments having different blending ratios as shown in Table 1. This table represents different treatment scenarios (T1 to T7) based on the proportion of water sourced from sewage water, groundwater, and surface water. Each treatment scenario has a specific percentage distribution of these water sources.

Table 1: Irrigation treatments

Treatment	Sewage water	Ground water	Surface water
T1	100 % of In	0 % of In	0 % of In
T2	66.66 % of In	33.33 % of In	0 % of In
T3	33.33 % of In	66.66 % of In	0 % of In
T4	0 % of In	100 % of In	0 % of In
T5	66.66 % of In	0 % of In	33.33 % of In
T6	33.33 % of In	0 % of In	66.66 % of In
T7	0 % of In	0 % of In	100 % of In

Note: In = Nos. of Irrigations

As sewage water is rich in Nitrogen, it is essential to explore possibilities of saving in application of Nitrogenous fertilizer. With this objective, three fertilizer treatments with varying levels of application of nitrogenous fertilizer were considered as shown in Table-2. N1 reflects application of full recommended amount of nitrogenous fertilizer. N2 means application of reduced amount i.e. three-fourths of the recommended quantity. N3 indicates application of half of the recommended nitrogenous fertilizer.

Table 2: Fertilizer treatments

Treatment	Nitrogenous fertilizer
N1	100 % of recommended dose
N2	75 % of recommended dose
N3	50 % of recommended dose

In order to analyse long term effects of wastewater irrigation, the experiments were replicated three times during three subsequent years as mentioned in Table-3. This experimental design aims at assessing long-term effects of different treatments (e.g., fertilizer application, irrigation methods) on wheat growth and yield over three successive trials to have better statistical accuracy and reliability of the findings.

Table 3: Replications of Experiments

Experiment	Replication
Wheat grown during 1 st Year	I
Wheat grown during 2 nd Year	II
Wheat grown during 3 rd Year	III

3. RESULTS AND DISCUSSION

Wheat yield obtained under seven irrigation treatments and three fertilizer treatments during Replication-I is shown in Table 4. The maximum yield recorded is 5177.95 kg/ha under T2 at N2. The minimum yield recorded is 3180.03 kg/ha under T5 at N1.

Table 4: Wheat Yield (kg/ha) Analysis (Replication-I)

Treatment	T1	T2	T3	T4	T5	T6	T7
N1	4978.16	4328.83	4412.08	4795.01	3180.03	4645.17	4844.96
N2	4328.83	5177.95	3929.25	4378.78	3762.75	4012.49	3846
N3	4462.02	4844.96	4478.68	4611.87	3612.91	4428.73	4145.69

Table-5 shows Wheat yield obtained under each irrigation treatments and fertilizer treatments during Replication-II. Highest Yield of 5705.64 kg/ha was reported under T5 at N1, indicating an outstanding response to this specific treatment. Lowest Yield of 3845.36 kg/ha was reported under T4 at N1, showing relatively poor performance.

Table 5: Wheat Yield (kg/ha) Analysis (Replication-II)

Treatment	T1	T2	T3	T4	T5	T6	T7
N1	5316.3	4638.97	4420.12	3845.36	5705.64	4312.57	4153.65
N2	5465.26	4215.36	4582.42	4206.97	5124.78	4250.92	4563.71
N3	5265.34	4215.21	4322.51	4003.68	5124.28	4435.28	4392.03

Wheat yield obtained under each irrigation treatments i.e. T1 to T7 and fertilizer treatments i.e. N1 to N3 during Replication-III is mentioned in Table-6. Highest Yield of 5865.24 kg/ha was recorded under T5 at N1, indicating the best-performing condition in this replication. Lowest Yield of 4158.75 kg/ha was observed under T4 at N3, showing the least productive condition in this dataset.

Table 6: Wheat Yield (kg/ha) Analysis (Replication-III)

Treatment	T1	T2	T3	T4	T5	T6	T7
N1	5326.52	4675.62	4431.18	4298.29	5865.24	4512.39	4200.16
N2	5625.98	4352.21	4756.34	4322.58	5378.96	5143.27	4651.54

N3	5305.28	4452.01	4410.21	4158.75	5268.21	4487.13	4431.37
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Fig. 1 shows wheat yield response to various treatments for each replication.

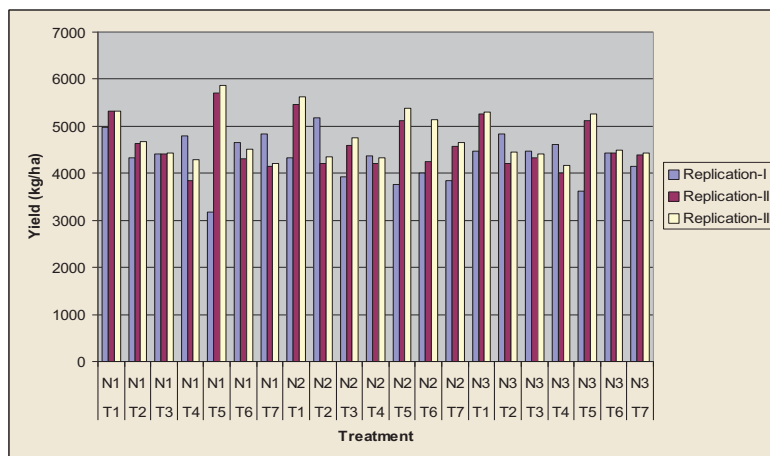


Figure 1. Wheat yield response to various treatments

Two factor Analysis of Variance (ANOVA) was performed to evaluate effects of two variables i.e. fertilizer treatments (Factor 1) and irrigation treatments (Factor 2) for Wheat yield as shown in Table-7. The interaction between water source treatments (T1-T7) and nitrogen levels (N1-N3) shows variations in wheat yield, suggesting that both water quality and nitrogen application influence crop performance.

Table 7: Two factor ANOVA (Wheat yield in kg/ha)

Treatment		Factor 2							Mean
		T1	T2	T3	T4	T5	T6	T7	
Factor 1	N1	5206.99	4547.81	4421.13	4312.89	4916.97	4490.04	4399.59	4613.63
	N2	5140.02	4581.84	4422.67	4302.78	4755.50	4468.89	4353.75	4575.06
	N3	5010.88	4504.06	4403.80	4258.10	4668.47	4450.38	4323.03	4516.96
	Mean	5119.30	4544.57	4415.87	4291.25	4780.31	4469.77	4358.79	4568.55

The results of two factor ANOVA are interpreted by looking at Sum of Squares (SS), degrees of Freedom (df), Mean Squares (MS), F ratios & p Values for Wheat yield as shown in Table 8. This table presents the results of an Analysis of Variance (ANOVA), assessing the effects of two factors (nitrogen fertilizer levels and water source treatments) and their interaction on wheat yield (kg/ha).

Table 8: ANOVA Table (Wheat yield in kg/ha)

Source	SS	df	MS	F	p-value
Factor 1	99462.41	2.00	49731.21	0.17	0.85
Factor 2	4524334.85	6.00	754055.81	2.50	0.04
Interaction	81712.71	12.00	6809.39	0.02	1.00
Error	12643969.77	42.00	301046.90		
Total	17349479.75	62.00			

Fig. 2 and Fig. 3 represent interaction plot by factor 1 (fertilizer treatments) and factor 2 (irrigation treatments) respectively.

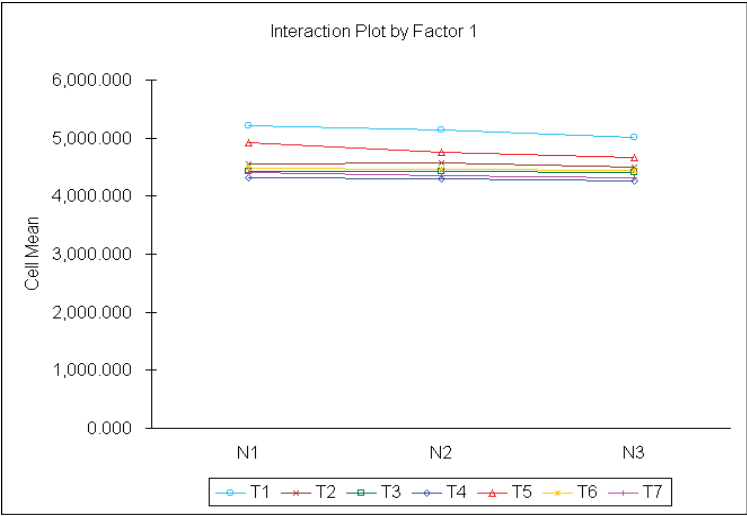


Figure 2. Interaction Plot by Factor 1 (Wheat Yield in kg/ha)

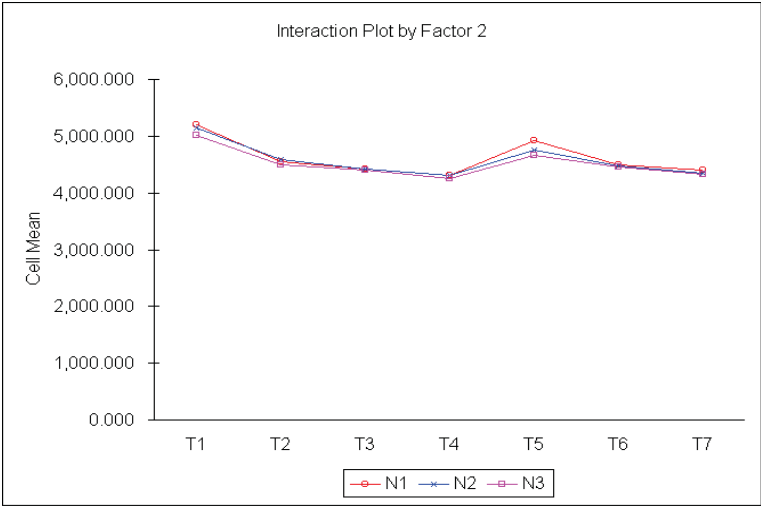


Figure 3. Interaction Plot by Factor 2 (Wheat Yield in kg/ha)

As far as individual Irrigation Treatment is concerned, T1 and T4 reflect highest and lowest yield level respectively. As far as individual Fertilizer Treatment is concerned, N1 and N3 reflect highest and lowest yield level respectively. As far as combination of Irrigation Treatment and Fertilizer Treatment are concerned, T1N1 and T4N3 reflect highest and lowest yield level respectively.

The protein content in Wheat under seven irrigation treatments and three fertilizer treatments during Replication-I is shown in Table 9. Highest Protein Content of 14.2% was recorded under T3 at N2, indicating that this treatment and nitrogen level combination promoted maximum protein accumulation. Lowest Protein Content of 12.7% was observed under T6 at N1 and T5 at N2, suggesting relatively lower protein synthesis in these conditions.

Table 9: Analysis of Protein Content (%) in Wheat (Replication-I)

Treatment	T1	T2	T3	T4	T5	T6	T7
N1	12.8	13.0	12.8	13.2	12.9	12.7	13.2
N2	13.0	12.9	14.2	13.4	12.7	13.4	12.8
N3	12.8	13.9	13.2	13.2	12.9	13.9	13.5

Table-10 shows protein content in Wheat under each irrigation treatments and fertilizer treatments during Replication-II. Highest Protein Content of 14.1% was recorded under T1 at N1 and T5 at N3, indicating that these conditions favored maximum protein accumulation. Lowest Protein Content of 12.7% was observed under T4 at N3, suggesting a weaker response in this treatment.

Table 10: Analysis of Protein Content (%) in Wheat (Replication-II)

Treatment	T1	T2	T3	T4	T5	T6	T7
N1	14.1	13.8	13.8	13.9	13.9	13.9	13.5
N2	14.0	13.8	13.6	12.8	13.9	13.3	13.0
N3	14.0	13.8	13.6	12.7	14.1	13.7	13.4

Table 11 presents the protein content (%) in wheat for different treatments (T1–T7) under three nitrogen levels (N1, N2, and N3) in the third replication of the experiment. Highest Protein Content of 16.4%, was reported under T1 at N1, indicating that this treatment with N1 provided the most favorable conditions for protein accumulation. Lowest Protein Content of 13.5% was observed under T7 at N3, showing the least protein content among all treatments.

Table 11: Analysis of Protein Content (%) in Wheat (Replication-III)

Treatment	T1	T2	T3	T4	T5	T6	T7
N1	16.4	16.2	15.6	14.3	15.8	14.9	13.8
N2	16.2	16.2	14.2	15.1	15.8	14.8	14.8
N3	16.3	15.1	15.2	14.8	15.2	13.9	13.5

Figure 4 shows protein content level in wheat grains response to various treatments for each replication.

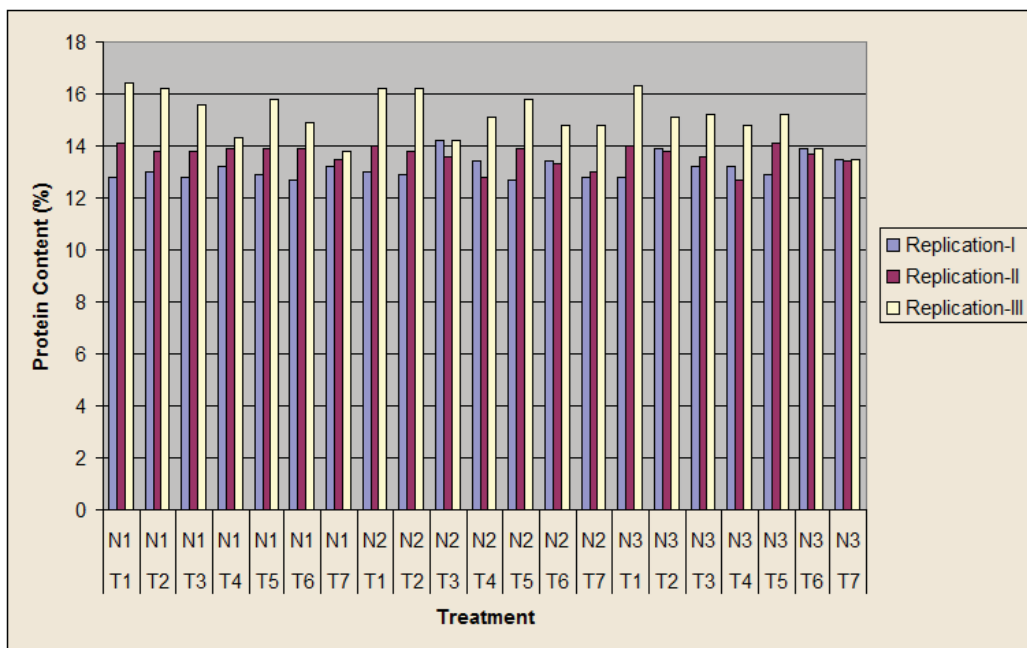


Figure 4. Protein content level in Wheat grains

Two factor Analysis of Variance (ANOVA) was performed to evaluate effects of two variables i.e. fertilizer treatments (Factor 1) and irrigation treatments (Factor 2) for protein content in Wheat as shown in Table-12. This table presents the results of a two-factor ANOVA analyzing wheat-protein content (%) under different treatments.

Table 12: Two factor ANOVA (Wheat-Protein Content in %)

Treatment		Factor 2						
		T1	T2	T3	T4	T5	T6	T7
Factor 1	N1	14.43	14.33	14.07	13.80	14.20	13.83	13.50
	N2	14.40	14.30	14.00	13.77	14.13	13.83	13.53
	N3	14.37	14.27	14.00	13.57	14.07	13.83	13.47
	Mean	14.40	14.30	14.02	13.71	14.13	13.83	13.50
		Mean						
		13.99						

The results of two factor ANOVA are interpreted by looking at Sum of Squares (SS), degrees of Freedom (df), Mean Squares (MS), F ratios & p Values for protein content in Wheat as shown in Table 13. This table shows the results of an Analysis of Variance (ANOVA) to assess the effects of nitrogen fertilizer levels (Factor 1), water source treatments (Factor 2), and their interaction on wheat protein content (%).

Table 13: ANOVA Table (Wheat-Protein Content in %)

Source	SS	Df	MS	F	p-value
Factor 1	0.08	2.00	0.04	0.03	0.97
Factor 2	5.65	6.00	0.94	0.64	0.69
Interaction	0.07	12.00	0.01	0.00	1.00
Error	61.47	42.00	1.46		
Total	17349479.75	62.00			

Figure. 5 and Figure 6 represent interaction plot by factor 1 (fertilizer treatments) and factor 2 (irrigation treatments) respectively.

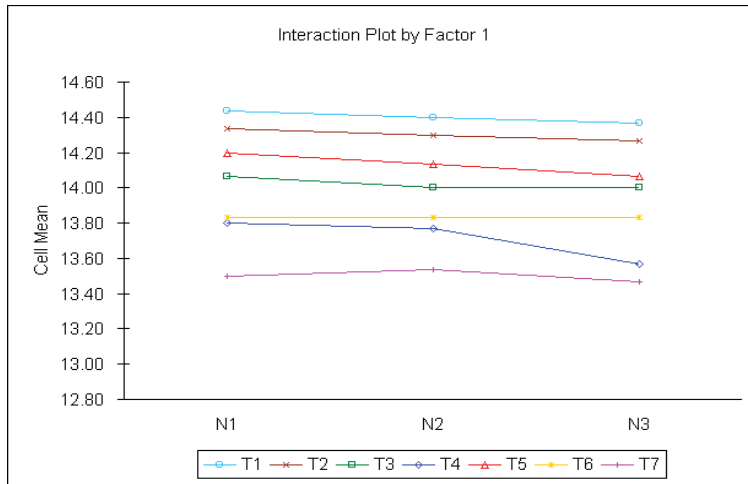


Figure 5. Interaction Plot by Factor 1 (Wheat-Protein Content in %)

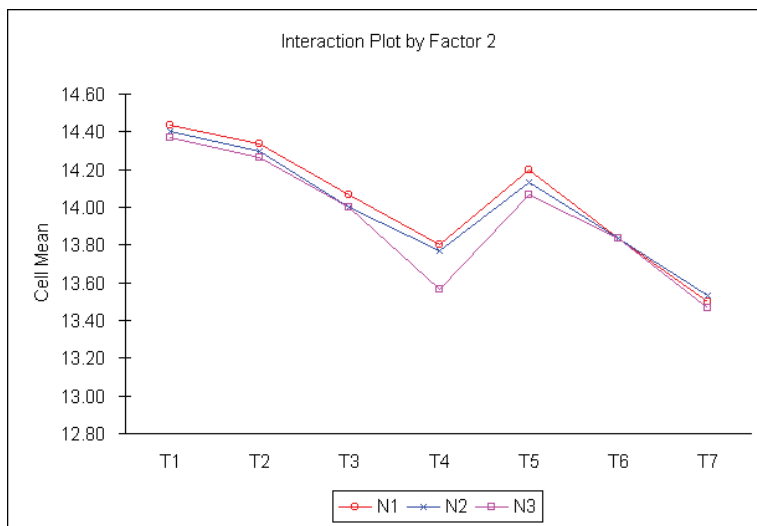


Figure 6. Interaction Plot by Factor 2 (Wheat-Protein Content in %)

As far as individual Irrigation Treatment is concerned, T1 and T7 reflect highest and lowest Protein content respectively. As far as individual Fertilizer Treatment is concerned, N1 and N3 reflect highest and lowest Protein content respectively. As far as combination of Irrigation Treatment and Fertilizer Treatment are concerned, T1N1 and T7N3 reflect highest and lowest Protein content respectively.

4. CONCLUSION

By performing hypothesis testing (two factor analysis of variance), it is found that main effects of Irrigation Treatment on Wheat yield are significant whereas main effects of Fertilizer Treatment on the same are non-significant at the 0.05 significance level. The p-value associated with the irrigation treatment factor is less than the predetermined significance level (0.05). This indicates that variations in irrigation practices lead to statistically significant differences in wheat yields. The F-statistic for irrigation treatment is sufficiently large, suggesting that the between-group variability (due to different irrigation levels) is considerably greater than the within-group variability (natural fluctuations in yield). Irrigation treatment (Factor 2) significantly affects wheat yield, meaning the type of water used plays a critical role in determining yield.

The p-value for the fertilizer treatment factor exceeds 0.05, implying that changes in fertilizer application do not produce statistically significant changes in wheat yields within the scope of this study. The F-statistic for fertilizer treatment is low, indicating that the between-group variability (due to different fertilizer levels) is not substantially greater than the within-group variability. Nitrogen fertilizer levels (Factor 1) do not have a significant impact, suggesting that reducing nitrogen application does not drastically affect yield in this experiment.

Neither nitrogen fertilizer levels nor water source treatments significantly affect wheat protein content. There is no significant interaction between the two factors, meaning they do not influence each other in determining protein levels. The analysis indicates that protein content in wheat is relatively stable regardless of nitrogen application rate and water source composition.

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