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Yield, Nutrient Content and Uptake by Wheat (*Triticum aestivum* L) as Influenced by FYM and Sources of Irrigation Water

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Abstract: The multilocation trials were conducted on wheat (*Triticum aestivum* L.) with farmyard manure (FYM) and sources of irrigation water at farmers' fields in Sami and Harij talukas of Patan district, North Gujarat Agro-climate Zone of Gujarat during four successive rabi season of 2014-15, 2015-16, 2016-17 and 2017-18. The experiment consisted of two levels of FYM (0 and 10 t FYM ha^{-1}) and three sources of irrigation water viz., sole tube well water, sole canal water and substitute irrigation of tube well and canal water. The trial was arranged in factorial randomized block design with four replications. The results revealed that application of FYM and source of irrigation had a noteworthy consequence on grain and straw yield of wheat on pooled basis. The treatment 10 t FYM ha^{-1} and alternate application of tube well and canal water resulted in higher grain and straw yield, nitrogen, phosphorus and potassium content and uptake by wheat.

Key words: Canal water, tube well water, FYM, nutrient content, nutrient uptake, wheat

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Wheat cultivation in India spans an area of approximately 30.47 million hectares, yielding an average output of 3,507 kg ha^{-1} (Anonymous, 2022). However, Gujarat lags behind states like Punjab and Haryana in wheat production, primarily due to its arid and semi-arid climate, as well as a shorter winter season. Salt-affected soils are prevalent in several regions of Gujarat, where high salt content and poor nutrient availability present significant agricultural challenges. The state cultivates wheat on around 1.29 million hectares, yielding about 4.10 million tonnes with a productivity rate of 3,174 kg ha^{-1} (Anonymous, 2023). In Gujarat, wheat is grown under both irrigated and rainfed conditions, ranking 8th in area, 6th in production, and 5th in productivity across India. Key wheat-producing districts include Junagadh, Ahmedabad, Sabarkantha, Rajkot, Kheda, Banaskantha, Mehsana, and Bhavnagar.

Soil and water are critical natural resources that underpin human survival. However, the increasing global population and rising living standards exert substantial pressure on these resources. Moreover, various environmental hazards have contributed to declining soil fertility, directly affecting agricultural productivity on both arable and non-arable lands. In arid and semi-arid regions, crop production heavily relies on irrigation, which is particularly vital in hot and dry climates. These areas often require irrigation water that is free from harmful concentrations of soluble salts, which can adversely affect both plant health and soil nutrient properties. Unfortunately, high-quality water in sufficient quantities is rarely available to meet the irrigation needs of all crops. Consequently, farmers frequently resort to using irrigation water with elevated levels of dissolved salts or residual sodium carbonate (RSC), resulting in reduced crop yields. The indiscriminate use of such water can lead to crop failures and worsen the development of saline or sodic soils, necessitating costly and labor-intensive reclamation efforts.

Nevertheless, when saline and sodic water is effectively managed, it can facilitate successful crop cultivation (FAO, 1988). However, excessive groundwater extraction has raised concerns about deteriorating water quality, particularly in semi-arid and arid ecosystems. Overexploitation has led to exacerbating salinity and sodicity issues, posing significant challenges to sustainable agriculture. This study aims to assess the impact of poor-quality groundwater on wheat yield, nutrient content, and nutrient uptake.

In the arid and semi-arid regions of Gujarat, poor-quality water is frequently utilized for crop irrigation. High concentrations of soluble salts in this water are known to diminish crop yields and reduce soil water infiltration capacity (McNeal, 1974; Shainberg and Levy, 1992; Qadir *et al*., 2000). To tackle the challenges associated with soil salinity, a variety of strategies have been developed, including leaching excess salts, blending and recycling saline drainage water, selecting salt-tolerant crop varieties, and implementing appropriate agronomic practices (Rhoades *et al*., 1992). Effective salinity management necessitates a thorough understanding of salt and water movement within the soil profile, as well as the ability to predict crop responses to variations in soil water and salinity under different climatic and agronomic conditions (Ferrer and Stockle, 1999). In this context, the current research is focused on evaluating the performance of wheat (*Triticum aestivum* L.) using farmyard manure (FYM) and various sources of irrigation water.

Materials and Methods

Multilocation trials were conducted in the Sami (Location I) and Harij (Location II) talukas of Patan district, situated in the North Gujarat Agro-climatic Zone-IV, during four consecutive rabi seasons spanning 2014-15, 2015-16, 2016-17, and 2017-18. These experiments took place on farmers' fields under the guidance of the Department of Agricultural Chemistry and Soil Science at C.P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar, Gujarat, India.

The Sami-Harij region features a semi-arid and subtropical climate characterized by hot summers and cold winters. The monsoon season typically begins in July and retreats by the end of September, with the majority of rainfall occurring during the southwest monsoon. July and August are particularly noted for their heavy showers, contributing to an average annual rainfall ranging from 552 to 994 mm. During the trial period, average minimum and maximum temperatures were reported at 19.5°C and 32.5°C, respectively.

The soil at the trial sites is classified as loamy sand with an alkaline response. It exhibits low levels of organic carbon, intermediate levels of available P_2O_5, and medium to high levels of available K_2O at both locations (Table 1). Seed and straw yields were recorded and analyzed for various chemical parameters. The statistical analysis was performed using Fisher's analysis of variance technique, and treatments were compared at a 5% significance level.

The experimental design incorporated two levels of farmyard manure (FYM): F0 (0 t ha^{-1}) and F1 (10.0 t ha^{-1}), as well as three sources of irrigation water: I1 (sole application of tube well water), I2 (sole application of canal water), and I3 (alternating applications of tube well and canal water). The quality of both irrigation and tube well water is presented in Table 1. Each treatment was replicated four times using a randomized block design with a factorial approach. The wheat variety Raj-3077 was sown for the trials.

Results and Discussion

Yield and economics

Effect of FYM: The data regarding the effects of farmyard manure (FYM) application on the

Table 1. Initial analytical data of loamy sand soil and water quality analysis of different sources

A. Initial soil fertility status

Soil parameters	Location-I				Location-II			
	2014-15	2015-16	2016-17	2017-18	2014-15	2015-16	2016-17	2017-18
pH $_{(1:2.5)}$	7.51	7.48	7.29	7.39	7.95	8.08	7.91	7.85
EC $_{(1:2.5)}$ (dS m^{-1})	2.65	2.48	2.54	2.39	1.39	1.28	1.31	1.24
Organic carbon (%)	0.29	0.33	0.34	0.31	0.32	0.29	0.35	0.31
Available P_2O_5 (kg ha^{-1})	43.25	40.25	43.65	38.98	36.25	40.65	37.25	41.35
Available K_2O (kg ha^{-1})	271	265	259	270	275	251	265	271

B. Quality assessment of irrigation water during commencement of experiment

Water sources	Location-I					Location-II				
	EC (µmhos cm^{-1})	pH	SAR	Chloride (meq l^{-1})	Class	EC (µmhos cm^{-1})	pH	SAR	Chloride (meq l^{-1})	Class
Tube well water	4900.0	7.50	9.08	29.10	C_4S_1	2950	8.45	13.34	40.10	C_4S_2
Canal water	230.0	7.95	1.36	1.10	C_1S_1	230.0	7.95	1.36	1.10	C_1S_1

yield and economics of wheat indicated that applying FYM significantly improved both grain and straw yields at both locations (Table 2). The application of 10 t ha^{-1} of FYM resulted in markedly higher yields of grain (5130 kg ha^{-1} and 4940 kg ha^{-1}) and straw (6517 kg ha^{-1} and 6252 kg ha^{-1}) at both locations (Fig. 1). However, the net returns and benefit-to-cost (B:C) ratio were higher in plots without FYM application at both locations. Beneficial effect of FYM can be attributed to its role in supplying additional plant nutrients and enhancing the soil's physical,

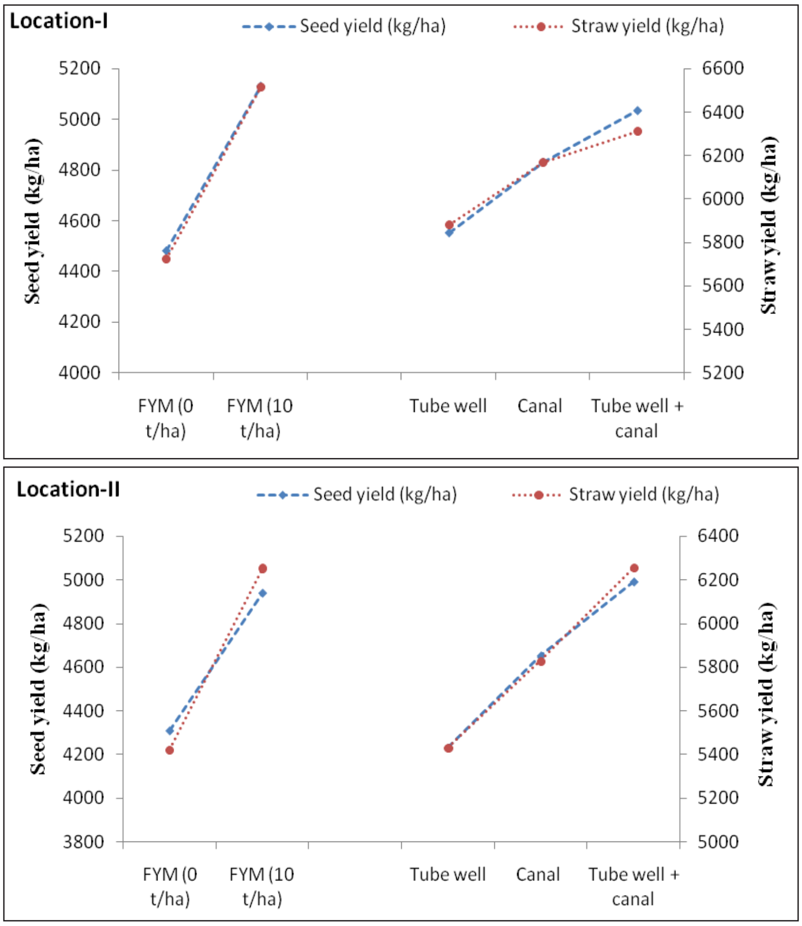

Fig. 1. Grain and straw yield of wheat in response to FYM and irrigation water sources (Pooled data of 4 years).

Table 2. Effect of different levels of FYM and irrigation sources on yield and economics of wheat (Pooled data of 4 years)

Treatments	Location-I				Location-II			
	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Net returns (Rs ha^{-1})	B: C ratio	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Net returns (Rs ha^{-1})	B: C ratio
FYM levels (t ha^{-1})								
F_0: 0	4481	5723	57420	2.81	4310	5422	53852	2.70
F_1: 10	5130	6517	54396	2.14	4940	6252	50567	2.06
SEm±	53.5	62.4	1026.0	0.02	66.5	105.6	1355.7	0.04
CD (p=0.05)	151.3	176.5	2902.3	0.07	188.0	298.8	NS	0.10
Irrigation water								
I_1: Tube well	4552	5879	50871	2.34	4231	5430	44409	2.17
I_2: Canal	4830	6169	56589	2.50	4653	5827	52829	2.41
I_3: Tube well + Canal	5034	6313	60263	2.59	4991	6254	59389	2.56
SEm±	65.5	76.4	1256.5	0.03	81.4	129.4	1660.3	0.04
CD (p=0.05)	185.3	216.2	3554.6	0.09	230.3	366.0	4696.9	0.12

chemical, and biological properties. Increased root metabolism leads to enhanced absorption of moisture and other nutrients, resulting in higher overall production.

Similar findings were reported by Kumar *et al*. (2010) and Chauhan *et al*. (2011), who noted that the higher yields can be attributed to the fact that organic manures provide readily available nutrients, such as nitrogen, to plants. Additionally, these organic amendments improve the stability of water aggregates in the soil, thereby enhancing soil structure. The improvement in soil structure due to FYM application creates a more favorable environment for root development, further contributing to increased yield. The high cost of FYM is the result of reduction in B:C ration after its application.

Effect of sources of irrigation water

Sources of irrigation water had a significant effect on grain and straw yield of wheat at both the locations (Table 2). The alternate application of tube well and canal water resulted in higher grain (5034 and 4991 kg ha^{-1}) and straw (6313 and 6254 kg ha^{-1}) yield and higher net return and B:C ratio as compared to the application of tube well or canal water alone. Reduction in the grain yield due to salinity has also been observed by Saqib *et al*. (2004) and Ghogdi *et al.* (2012). Due to higher concentrations of salts in the leaves different metabolic processes like photosynthesis and protein synthesis are negatively affected which result in the reduced grain weight (Ibrahim, 2003). There was a positive relationship of grain yield and alternate application of canal water and tube well water in this study which could be due to presence of some soluble nutrients in tubewell water.

Nutrient content and uptake

Effect of FYM: The application of FYM (farmyard manure) significantly affected the nitrogen (N), phosphorus (P), and potassium (K) content in wheat grain and straw (Table 3). The use of 10 t FYM ha^{-1} resulted in higher nitrogen content in grain (2.30% and 2.26%) and straw (1.18% and 1.20%) on a pooled basis across both locations than control. Similarly, nitrogen uptake was significantly higher with 10 t FYM ha^{-1}. These results align with the findings of Dahiya *et al*. (1987) and Singh *et al*. (1994), which attribute the increased nitrogen content to enhanced root growth, improved nitrogen availability due to FYM decomposition, and higher microbial activity in the soil.

Phosphorus content in grain (0.341% and 0.322%) and straw (0.202% and 0.155%) was also significantly higher with 10 t FYM ha^{-1}. Corresponding phosphorus uptake was 17.6 and 13.2 kg ha^{-1} at Location I and 17.57 and 9.70 kg ha^{-1} at Location II for grain and straw, respectively. The improvement in phosphorus availability is likely due to better root growth and increased soil phosphorus availability, consistent with reports by Singh *et al*. (1994) and Dahiya *et al*. (1987).

For potassium, 10 t FYM ha^{-1} significantly increased grain (0.704% and 0.707%) and straw (1.40% and 1.43%) potassium content, with higher potassium uptake observed at both locations. At Location I, uptake was 36.07 and

Table 3. Effect of different levels of FYM and irrigation sources on nutrient content in wheat (Pooled data of 4 years)

Treatments	Location-I						Location-II					
	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
FYM levels (t ha^{-1})												
F_0: 0	2.19	1.10	0.307	0.185	0.654	1.309	2.14	1.11	0.295	0.152	0.651	1.313
F_1: 10	2.30	1.18	0.341	0.202	0.704	1.402	2.26	1.20	0.322	0.155	0.707	1.426
SEm±	0.03	0.01	0.007	0.006	0.009	0.017	0.04	0.02	0.005	0.003	0.011	0.023
CD (P=0.05)	0.10	0.04	0.020	0.016	0.026	0.049	0.10	0.05	0.015	NS	0.031	0.065
I_1: Tube well	2.20	1.12	0.311	0.181	0.660	1.321	2.17	1.12	0.292	0.148	0.657	1.340
I_2: Canal	2.25	1.15	0.324	0.193	0.679	1.358	2.20	1.15	0.308	0.151	0.677	1.365
I_3: Tube well + Canal	2.28	1.14	0.338	0.206	0.699	1.388	2.24	1.19	0.325	0.162	0.701	1.402
SEm±	0.04	0.02	0.009	0.007	0.011	0.021	0.04	0.02	0.006	0.003	0.014	0.028
CD (P=0.05)	NS	NS	NS	0.020	NS	NS	NS	NS	0.018	0.010	NS	NS

91.58 kg ha^{-1} for grain and straw, respectively, while at Location II, uptake was 34.89 and 88.73 kg ha^{-1}. The increase in potassium is attributed to the addition of organic matter, which enhances potassium availability through reduced fixation, nutrient release during organic matter decomposition, and improved nutrient absorption. These findings align with those of Dahiya *et al*. (1987).

Overall, the application of 10 t FYM ha^{-1} improved nutrient content and uptake, demonstrating its potential to enhance soil fertility and wheat productivity.

Effect of sources of irrigation water

The sources of irrigation water did not cause significant changes in nitrogen (N), phosphorus (P), and potassium (K) content in wheat grain and straw, except for phosphorus content in straw at Location I (Table 3). Alternate irrigation with tube well and canal water significantly increased phosphorus content in wheat grain (0.325%) and straw (0.162%) on a pooled basis. However, for phosphorus content in straw at Location II, it was statistically at par with sole canal water irrigation.

Nutrient uptake (Table 4) revealed that alternate irrigation with tube well and canal water led to a significant increase in nitrogen (115.2 and 72.8 kg ha^{-1}), phosphorus (17.1 and 13.0 kg ha^{-1}), and potassium (35.2 and 87.9 kg ha^{-1}) uptake by wheat grain and straw on a pooled basis at Location I over tube well irrigation. However, these values were

Table 4. Effect of different levels of FYM and irrigation sources on nutrient uptake by wheat (Pooled data of 4 years)

Treatments	Location-I						Location-II					
	Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-2})		Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
FYM levels (t ha^{-1})												
F_0: 0	98.2	63.1	13.8	10.5	29.3	75.0	92.0	60.4	12.8	8.3	28.1	71.2
F_1: 10	118.4	77.0	17.6	13.2	36.1	91.6	111.9	75.1	16.0	9.7	34.9	88.7
SEm±	2.17	1.21	0.41	0.37	0.54	1.49	2.14	1.62	0.33	0.22	0.67	1.59
CD (p=0.05)	6.13	3.41	1.16	1.04	1.53	4.22	6.04	4.58	0.94	0.62	1.88	4.49
Irrigation water												
I_1: Tube well	100.5	66.1	14.2	10.6	30.0	77.9	91.6	60.9	12.4	8.0	27.9	72.7
I_2: Canal	109.3	71.3	15.7	11.9	32.8	84.0	102.3	67.5	14.4	8.8	31.6	79.5
I_3: Tube well + Canal	115.2	72.8	17.1	13.0	35.2	87.9	111.9	74.8	16.3	10.2	35.0	87.7
SEm±	2.66	1.48	0.50	0.45	0.66	1.83	2.62	1.98	0.41	0.27	0.82	1.94
CD (p=0.05)	7.51	4.18	1.42	1.28	1.87	5.17	7.40	5.61	1.15	0.76	2.31	5.50

statistically similar to those under sole canal water irrigation for nitrogen uptake (109.3 and 71.3 kg ha^{-1}), phosphorus uptake (15.7 and 11.9 kg ha^{-1}), and potassium uptake by straw (84.0 kg ha^{-1}). Similar trend was observed at location II. The alternate use of tube well and canal water improved nutrient availability by dissolving mineral elements and salts in the soil, allowing crops to utilize essential nutrients while leaching harmful salts below the root zone. The precipitation and dissolution of salts in the soil profile were influenced by irrigation frequency, with less water application leading to more salt precipitation, especially under dry conditions.

Conclusion

Aapplication of 10 t FYM ha^{-1} coupled with h alternate irrigation using tube well and canal water, demonstrated significant advantages for wheat production in the North Gujarat region. This approach not only improved nutrient availability and uptake of nitrogen, phosphorus, and potassium in wheat grain and straw but also enhanced overall soil health by balancing salt levels in the root zone. The alternate irrigation effectively dissolved and mobilized essential nutrients while leaching harmful salts, thereby optimizing nutrient utilization and minimizing the risk of salinity build-up. This integrated strategy provides a sustainable solution for improving wheat yield and maintaining soil fertility in arid and semi-arid ecosystems.

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