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Impact of soil moisture-based irrigation, mulching, and nitrogen levels on wheat growth and yield in sub-tropical Jammu, India

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Abstract
Wheat (*Triticum aestivum* L.) stands as a vital global cereal crop, providing sustenance for approximately 40% of the world's population. This study aimed to assess the influence of soil moisture-based irrigation regimes, mulching, and nitrogen levels on wheat growth, yield attributes, and grain yield during the Rabi season 2020-21 in the sub-tropical region of Jammu, India. The experiment, conducted at the Research Farm, WMRC, Sher-e-Kashmir University of Agricultural Sciences and Technology, involved a split-split plot design with three replications. Three moisture depletion regimes (30% MAD, 40% MAD, and 50% MAD) constituted the main plot, mulch (No mulch and 6 tonnes/ha straw mulch) the sub-plot, and four nitrogen doses (0, 75, 100, and 125 kg/ha) the sub-sub plot. Results indicated that 40% MAD irrigation was optimal, yielding the highest grain yield (36.47 q/ha), closely followed by 50% MAD, while 30% MAD exhibited the lowest grain yield. Wheat crops with 6 tonnes/ha of mulch demonstrated superior performance, emphasizing the positive impact of mulching on grain yield. Nitrogen supplementation significantly influenced grain yield, with the application of 125 kg N/ha resulting in the highest yield. The study provides valuable insights for optimizing agricultural practices in semi-arid regions, emphasizing the critical role of strategic irrigation, mulching and nitrogen application in enhancing wheat productivity. These findings contribute to sustainable agricultural practices, addressing food security challenges in similar agro-climatic conditions.

Keywords: Irrigation, straw mulch, nitrogen, grain yield

Introduction

Wheat (*Triticum aestivum* L.) stands as one of the fundamental cereal crops globally, providing a staple sustenance for approximately 40% of the world's populace, offering more calories and 20% of daily dietary protein compared to any other cereal (LACC/IGW, 2018) [14]. In India, wheat production has surged to 108.75 million tonnes, boasting an average national productivity of 3424 kg ha^{-1} as per the ICAR Report of 2021. This crop predominantly thrives in India's semiarid and arid regions throughout the Rabi season. Adequate water is crucial for facilitating optimal growth, balanced development, and increased yield across all crops. Insufficient water supply can significantly impede plant growth and yield (Hussain *et al*., 2004) [9].

Effective irrigation management is a critical aspect of agricultural management, directly impacting the efficient utilization of water resources by crops. Mulching stands out as a crucial agronomic practice aimed at conserving soil moisture and enhancing soil health. By definition, mulch refers to a protective layer of material placed or maintained on the soil surface. Mulches offer numerous advantages to crops, including erosion control, water conservation, mitigation of temperature fluctuations, elevation of soil organic matter levels, enhancement of soil structure, and suppression of weed growth. Research by Qin *et al*., (2015) [17] demonstrated that mulching led to a significant increase in crop yield, water use efficiency, and nitrogen use efficiency, with improvements of up to 60% compared to situations without mulch.

Nitrogen is crucial for the metabolic activities of plants, serving as a primary component and significant constituent, particularly in the formation of living tissues. Proteins, essential for various plant processes, are comprised of nitrogen.

Nitrogen is integral to proteins, phytochromes, compounds, coenzymes, chlorophyll, and nucleic acids, influencing virtually all biochemical processes within plants. The presence of nitrogen and its associated compounds is essential for wheat's growth and development, underscoring its importance (Kutman *et al*., 2011) [13]

The present investigation was undertaken to determine the soil moisture based irrigation regime affected by different irrigation scheduling, mulch and nitrogen levels on growth, yield attributes and yield of wheat crop in sub-tropical Jammu, India at the Research Farm WMRC, Chatha, SKUAST- Jammu.

Materials and Methods

The experiment was conducted during *Rabi* season 2020-21 at Research Farm, WMRC, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K, India. The subtropical Shivalik Himalayan foothills are home to the experimental site, which is located in the Union Territory of Jammu and Kashmir. The topsoil in the experimental field was sandy loam which had a moderately alkaline pH, poor organic carbon and nitrogen availability, and intermediate phosphorus and potassium levels. The experiment was carried out in split-split plot design with three replications consisting of three moisture depletion regimes (I_1=30% MAD, I_2=40% MAD and I_3=50% MAD) as a main plot, mulch (M_0 = No mulch and M_1 = 6 tonnes per hectare straw mulch) as a sub plot and 4 doses of nitrogen (N_0 = 0, N_1 = 75, N_2 = 100 and N_3 = 125 kg/ha.) as a sub-sub plot. The plot was ploughed once with the help of disc harrow and leveled it. Wheat (cv. HD 2967) seeds were sown manually by pora method. Rice residue mulch was applied manually according to treatments during the time of sowing. Nitrogen was applied as urea in three splits doses i.e., 50% at sowing time, 25% at CRI stage and remaining 25% at flowering stage according to treatments and full dosage of phosphorus @ 60 kg/ha and potassium @ 60 kg/ha through single super phosphate and muriate of potash respectively, applied as basal dose at sowing time. Plots were irrigated according to treatments following the depletion approach. Field was kept weed free by employing manual weeding 3-4 times during crop growth stages. The crop was harvested with sickles and tied in bundles with tag from each plot and left for sun drying. Threshing operation was also performed plot wise manually. The growth parameters *viz*. dry matter (g/m row length) yield attributes and yield *viz*. number of effective tillers/m^2, test weight (g), number of grains/ear and grains yield (q/ha) were recorded at the time of wheat harvesting. The data was statistically analyzed using OPSTAT software (Gomez and Gomez).

Result and Discussion

Dry Matter of Wheat (g/m row length)

Data presented in Table.1 and fig.1 prominently showing that dry matter accumulation (g/m row length) by wheat crop during the crop growing season of *rab*i 2020-21 was significantly influenced by irrigation levels, mulch levels and N levels at the time of harvesting.

Maximum dry matter accumulation (190.70 g/m row length) of wheat plants was observed in 30% MAD followed by 40% MAD (188.66). Whereas minimum dry matter accumulation (185.57 g/m row length) of wheat plants was observed in 50% MAD.As is apparent from the data, highest dry matter accumulation (190.61 g/m row length) was observed in wheat crop @ 6 tonnes/ha mulch during *rabi* season 2020-21.

The data presented in Table 2 revealed that wheat crop supplied with 125 kg N/ha recorded significantly highest (221.40 g/m row) dry matter accumulation followed by other N levels *viz*., 100 kg/ha and 75 kg/ha at harvest stage. However, lowest (144.92 g/m row length) dry matter accumulation was found with 0 kg N/ha during *rabi* season 2020-21. The higher dry mass of nitrogen treated plants could be connected with the positive effect of nitrogen in some important physiological processes. Andrew *et al*. (1968) [3] also reported similar results.

The interaction effects of irrigation levels, mulch levels and nitrogen levels were found non-significant for dry matter accumulation (g/m row length) at harvesting stage in *rabi* season 2020-21.

Number of tiller/m^2

It is evident from the data presented in Table1 and Fig.1 that tillers/m² by the wheat crop during the *rabi* growing seasons of 2020-21. Tillers/m² of wheat plants were influenced by irrigation levels, mulch levels, and N levels at the time of harvesting. Tillers/m² was statistically not significant, but numerically the values (330.21 tillers/m²) were higher in 30% MAD. Whereas, the minimum (310.00 tillers/m²) of wheat plants was observed at 50% MAD. As is apparent from the data, tillers/m² were significantly influenced by mulch levels. The maximum (329.67) tillers/m² were observed in wheat crop with 6 tonnes/ha of mulch during the *rabi* season of 2020-21.

The data presented in Table 3 revealed that the wheat crop supplied with 125 kg N/ha recorded the significantly highest (378.50) tillers/m², followed by other N levels *viz*., 100 kg/ha and 75 kg/ha at the harvest stage. However, the lowest (241.39) tillers/m² were found with 0 kg N/ha during the *rabi* season of 2020-21. The increase in the number of tillers under mulching in combination with irrigation can be explained in light of the role of soil water in increasing nutrient availability and its transport for utilization in cell growth and its differentiation in the production of tillers. Towa *et al*., (2013) [20] also observed an increase in tillers due to the application of mulch and attributed it to the increase in soil moisture contents and the reduction in evaporation from the soil.

The enhancement in tiller number with an increase in fertilizer dose is attributed to the rapid conversion of synthesized carbohydrates into protein and, consequently, the increase in the number and size of growing cells, resulting ultimately in an increased number of tillers (Singh and Agarwal, 2001) [18]. The interaction effect of irrigation levels, mulch levels, and nitrogen levels was found to be non-significant for tillers/m² at the harvesting stage in the years 2020-2021 under study.

Test weight (g)

A cursory glance at the data in Table.1 and fig.1 reveals that, unlike irrigation levels, the treatments of mulching levels, and nitrogen levels bring about significant variation in the 1000-grain weight (g) of wheat during the *rabi* season of 2020-21 experimentation. Although the test weight (g) was not statistically significant, numerically the values (37.02 g) were higher in 30% MAD irrigation, followed by 40% MAD irrigation (36.06 g), and 50% MAD irrigation (35.45 g) during the *rabi* season 2020-21. The response between mulched and no-mulched plots was statistically significant (37.34 vs. 35.01 g) during the *rabi* season 2020-21 regarding the test weight of wheat.

Regardless of irrigation and mulch levels, the nitrogen levels bring about significant variation in the test weight of wheat during the year 2020-2021 experimentation. The test weight tends to increase with increasing levels of nitrogen. While the lowest test weight was exhibited by the N0 treatment (27.16 g), the registered test weights were observed when the wheat crop was supplied with 75 kg N/ha (37.24 g), 100 kg N/ha (39.95 g), and 125 kg N/ha (40.37 g) in the year 2020-2021. The data imply that the test weight increased by 48.63%, 47.1%, and 37.1% during the *rabi* season 2020-21 compared to the respective no-nitrogen treatment.

The increased number of grains/spike with an increasing number of irrigation was previously reported by Brahma *et al*., (2007) [5]. Better moisture availability, either due to mulching or due to an increased number of irrigation, could be the reason for increased values of yield attributes. Increased 1000-grain weight in wheat under an increased number of irrigation was earlier reported by Ahmad and Kumar (2015) [1]. Khurshid *et al*. (2006) [12] reported that mulch increases soil moisture and nutrient availability to plant roots, leading to higher grain yield. It appears that the application of nitrogen increased the protein percentage, which, in turn, increased the grain weight. Similar results were also reported by Nelson *et al*. (1989) [16] and Kausar *et al*. (1993) [11].

Grains/ear

There was a pronounced and significant influence of irrigation, mulch, and nitrogen levels on the number of grains per ear of wheat (Table.1 and fif.1). The maximum number of grains per ear of wheat (35.00) was observed under I_1 (30% MAD irrigation), followed by I_2 (40% MAD irrigation) (34.38) and I_3 (50% MAD irrigation) (31.92) during the *rabi* season 2020-21, respectively.

It was also apparent from the data that the maximum number of grains per ear (34.39) was obtained with @ 6 tonnes/ha mulch as against no mulch (33.14) during the *rabi* season 2020-21, respectively. Mulch improved the grain/ear by 3.8% during 2020-2021 over the no-mulch treatment. For the given irrigation and mulch treatment, amongst the nitrogen supplement levels, N_4 treatment (125 kg N/ha) registered a significantly higher (37.61) number of grains per ear, followed by N_3 (100 kg N/ha) (36.00) and N_2 (75 kg N/ha) (33.33) during 2020-21, respectively. However, the least number of grains per ear (28.11) was recorded with N_1 (0 kg N/ha) during the respective years. Thus, treatments of N4, N_3, and N_2 enhanced the grains/ear by 33.8%, 28.0%, and 18.6% over the N1 treatment during the year 2020-2021.

Khurshid *et al*., (2006) [12] reported that mulch increases soil moisture and nutrient availability to plant roots, in turn, leading to higher grain yield. This trend might be due to the role of nitrogen in crop maturation, flowering, and fruiting, including seed formation. These results are in accordance with those of Thakur *et al*. (1981) [19]. The interaction effect of irrigation levels, mulch levels, and nitrogen levels were found to be non-significant for the number of grains per ear in the *rabi* season 2020-21.

Grain yield (q/ha)

It is evident from the data presented in Table.1 and Fig.1 that the grain yield (q/ha) of the wheat crop during the *rabi* seasons of 2020-21 was significantly influenced by irrigation levels, mulch levels, and N levels. The highest grain yield (36.47 q/ha) of the wheat crop was observed with 40% MAD, followed by 50% MAD (36.19 q/ha). Whereas, the lowest (35.37 q/ha) grain yield of the wheat crop was recorded with 30% MAD. As apparent from the data, the highest grain yield (36.26 q/ha) was observed in the wheat crop with 6 tonnes/ha of mulch during the *rabi* season 2020-21.

The data revealed that the wheat crop supplied with 125 kg N/ha recorded the significantly highest (42.19 q/ha) grain yield, followed by other N levels *viz*., 100 kg/ha and 75 kg/ha at the harvest stage. However, the minimum grain yield (25.07 q/ha) was recorded with 0 kg N/ha during the *rabi* season 2020-21. This is to be expected since drought stress might reduce the translocation of assimilates from leaves; this response, in addition to reduced photosynthesis in the leaves itself, contributes to lower grain yield. Conversely, water deficit at any growth stage reduces grain yield. These results are in line with Beshara (2012) [4] and Hammad-Salwa and Ali (2014) [8]. Khurshid *et al*., (2006) [12], who reported that mulch increases soil moisture and nutrients availability to plant roots leading to higher grain yield. It can be concluded that the increasing amount of nitrogen fertilizer consequently results in higher grain yield. These results are in conformity with El-Gizawy (2005) [6]; Mosaad *et al*., (2013) [21] and Gazia and Abd EL Aziz (2013) [7].

Data pertaining to fig.2 revealed that application of irrigation and N fertilizer levels show significant ($P< 0.05$) interaction effects. In each nitrogen treatment level with the irrigation level (40% MAD) shows significant interaction increase in N1:0 kg N/ha, N2:75 kg N/ha, N3:100 kg N/ha, and N4:125 kg N/ha *viz*., 26.0 q/ha, 37.7 q/ha, 39.7 q/ha and 42.7 q/ha productivity respectively. The highest interaction effect of irrigation levels with nitrogen levels was found to be among 40% MAD and N4:125 kg N/ha nitrogen level respectively as compared to interaction between irrigation levels 30% MAD and 50% MAD and nitrogen level N4:125 kg N/ha respectively in wheat crop in the 2020-2021 cropping year.

Table 1: Effect of irrigation, mulching and N fertilizer levels on Dry matter (g/m row length), effective tillers/m^2, Test weight (g), Number of grain/ear, Grain yield (q/ha)

Treatment	Dry matter (g/m row length) At Harvest	No. of effective tillers/m^2	Test weight (g)	Number of grain/ear	Grain yield (q/ha)
30% MAD	190.70	330.21	37.02	35.00	35.37
40% MAD	188.66	320.46	36.06	34.38	36.47
50% MAD	185.57	310.00	35.45	31.92	36.19
SEm (±)	0.76	8.76	0.62	0.30	0.14
CD (5%)	2.98	NS	NS	1.19	0.55
No mulch	186.01	310.78	35.01	33.14	35.76
Mulch @ 6 tonnes/ha	190.61	329.67	37.34	34.39	36.26
SEm (±)	0.52	5.45	0.58	0.31	0.16
CD (5%)	1.79	18.86	1.99	1.07	0.57
N1: 0 kg N/ha	144.92	241.39	27.16	28.11	25.07
N2: 75 kg N/ha	182.64	295.28	37.24	33.33	37.38
N3: 100 kg N/ha	204.27	365.72	39.95	36.00	39.38
N4: 125 kg N/ha	221.40	378.50	40.37	37.61	42.19
SEm (±)	0.97	7.54	0.67	0.54	0.17
CD (5%)	2.77	21.63	1.92	1.55	0.48
Interaction	NS	NS	NS	NS	S

***** MAD = Maximum allowable depletion

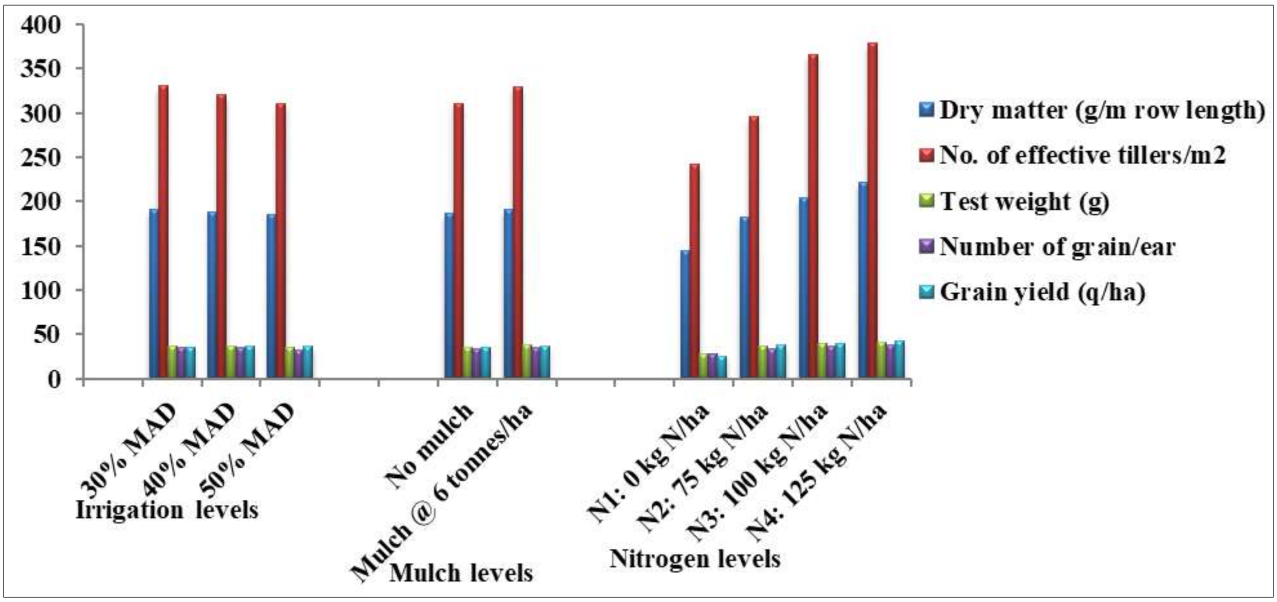

Fig 1: Effect of irrigation, mulching and N fertilizer levels on Dry matter (g/m row length), effective tillers/m^2, Test weight (g), Number of grain/ear, Grain yield (q/ha)

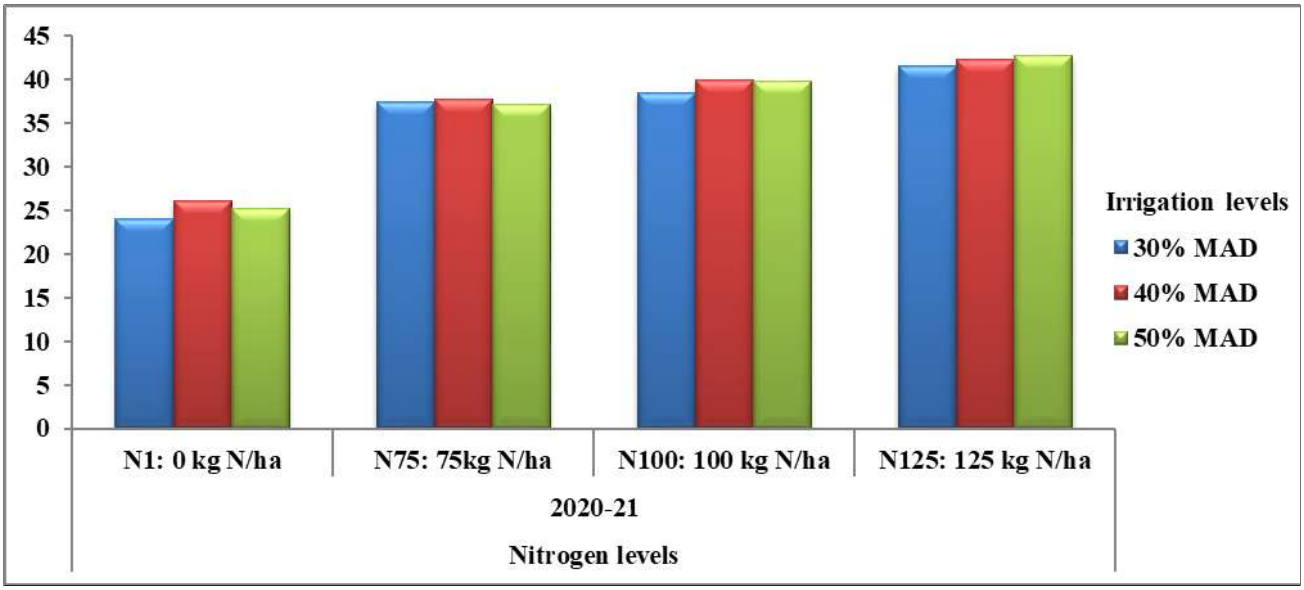

Fig 2: Interaction effect of irrigation levels and nitrogen levels on grain yield (q/ha) 2020-2021

Conclusion

The study investigated the impact of soil moisture-based irrigation regimes, mulching, and nitrogen levels on the growth, yield attributes, and grain yield of wheat (*Triticum aestivum* L.) in the sub-tropical region of Jammu, India, during the *Rabi* season 2020-21. Wheat, a staple food for 40% of the world's population, is crucial for global food security, providing substantial calories and dietary protein.

The results revealed significant effects of irrigation levels, mulching, and nitrogen application on various parameters. Notably, 40% moisture-aided deficit (MAD) irrigation emerged as optimal, yielding the highest grain yield (36.47 q/ha), followed closely by 50% MAD (36.19 q/ha), while 30% MAD recorded the lowest (35.37 q/ha) grain yield. Additionally, wheat crops with 6 tonnes/ha of mulch demonstrated superior performance, indicating the positive impact of mulching on grain yield.

Nitrogen supplementation played a crucial role, with the application of 125 kg N/ha resulting in significantly higher grain yield (42.19 q/ha). Conversely, the absence of nitrogen (0 kg N/ha) led to the lowest grain yield (25.07 q/ha), underlining the essential role of nitrogen in wheat development. The study highlighted the interactive significance of irrigation levels and nitrogen levels on grain yield.

In conclusion, the research provides valuable insights into optimizing agricultural practices for wheat cultivation in semi-arid regions. The findings emphasize the importance of strategic irrigation, mulching, and nitrogen application for enhancing wheat productivity, contributing to both food security and sustainable agricultural practices. These insights are particularly relevant for farmers and policymakers aiming to improve wheat yield in similar agro-climatic conditions.

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