



Effect of Tillage and Mulching on Growth and Yield Performance of Barley under Different Nitrogen and Irrigation Application Rates

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ABSTRACT

Background: Integrated management of soil, water and nutrient resources is critical in improving animal feed production sustainably as it is highly resource demanding. Barley is considered as an excellent choice for animal feed owing to its rich nutritional composition, energy content, palatability, versatility and economic feasibility. Implementing sustainable crop management practices that improve soil health as well as enhance water and nitrogen availability is critical for improving crop productivity and ensuring improved animal feed production in these challenging environments. In arid regions with scarce water resources and less fertile soil, an interplay between water availability and nitrogen fertilization plays a significant role in enhancing barley production. Thus adoption of conservation agricultural practices coupled with optimized irrigation and fertilization regime is crucial in establishing sustainable animal feed production in the region. However, much insight is not delivered in the area of interactive effects of irrigation and fertilization with conservational agricultural practices on sustainable intensification of animal feed production in arid and semi-arid lands. The study investigated the interactive effect of tillage, mulching, irrigation and nitrogen application rates on growth and yield performance of barley under Kuwait's environmental conditions.

Methods: The study was conducted at KISR Station for Research and Innovation-KSRI (29.3156°N, 47.8403°E), Kuwait. The effect of tillage and mulching on the growth and yield performance of barley was evaluated under combinations of three different irrigation (100% ET_c, 75% ET_c and 50% ET_c) and fertilization application rates (0 kg/ha, 50 kg/ha and 100 kg/ha). Split-split plot experimental design was employed with three replications to study the effect of different treatments on plant height, number of plants per square meter, spike length, number of spikes per square meter, biomass yield, grain weight, harvest index and residue yield.

Result: Tillage, mulching, irrigation and fertilization application rates imposed a significant interaction effect on barley biomass and grain yield. Minimum tilled plots with mulching under 100% ET_c irrigation and 100 kgN/ha recorded the highest biomass and residue yield. For grain yield, minimum as well as conventional tillage with mulching produced the highest value under 100% ET_c irrigation and 50 kgN/ha. Highest plant height and number of spikes per square meter was noted in plots with minimum tillage and mulching under 100% ET_c irrigation.

Key words: Animal feed, Conservation agriculture, Fertilization, Reduced tillage, Straw mulch.

INTRODUCTION

Improved animal feed production is of paramount importance as the demand for animal products is increasing with the growing population (FAO, 2012a). Consistent supply of animal feeds becomes crucial for meeting global demands as livestock requires a balanced diet with adequate nutrients essential for their growth, health and productivity (Makkar, 2018). The world's largest user of land resources is livestock where pasture and arable land dedicated to the production of feed constitutes 80% of the total agricultural land. One-third of global arable land is used to grow feed, while 26% of the Earth's ice-free terrestrial surface is used for grazing (FAO, 2012b). Livestock species mainly, sheep, goats, cattle and camels of hot arid environment of Kuwait depend mainly on imported grains, grain by-products and straws as feed ingredients. Due to the deterioration of rangelands, grazing of small ruminant animals has become impossible. Therefore, they are fed and managed in the feedlot intensive

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system of production (Razzaque, 1995). The use of locally available feed resources and improved feeding with balanced rations could significantly boost profitability for farmers (Coughenour and Makkar, 2012). Mostly, barley grains and barley straws constitute bulks of the ration of sheep, goats and cattle (Razzaque *et al.*, 2009). The grain

protein content ranges from 10-15% depending on the climatic and soil conditions under which the crop grows (Raj, 2023). Barley straw is used as animal feed at the vegetative stage or for silage, in West Asia, Africa and the Far East (Kling, 2004; Duke, 1983). It is a rapidly growing, shallow-rooted plant that is suitable for well-drained loamy to clayey loam soils with a pH between 5.0 and 8.3 and in less fertile marginal lands. Its incorporation into the soil enhances soil structure and water infiltration capacity (Valenzuela and Smith, 2002). Barley, is a widely adaptable crop, grown in highly productive environments as well as marginal lands (Randhawa *et al.*, 2020; Newton *et al.*, 2011). Moreover, it serves as the most drought and salt tolerant of the small grain cereals and is included in the list of the priority crops in the Agriculture Master Plan of the State of Kuwait (KISR, 1996).

The quality and quantity of animal feed are directly influenced by several factors which includes health of the soil (Silver *et al.*, 2021), selected crops, irrigation and fertilization regime (Ul-Allah *et al.*, 2014). Sustainable soil management practices such as reduced tillage and mulching contribute to improved soil health (Sharma and Bhardwaj, 2017), increased crop yields and higher-quality animal feed production (Al-Samin *et al.*, 2022). There exists a direct link between tillage and mulching practices and the production of animal feed (Molata *et al.*, 2023). Excessive or improper tillage practices negatively affect soil health, reducing nutrient availability and growth of crops (Angon *et al.*, 2023). Mulching helps retain soil moisture and nutrients, promoting growth of forage crops that are valuable for animal grazing or as feed supplements, ultimately benefitting animal health and productivity. Residue retention improves soil organic matter content and eventually improves fertilizer use efficiency of the crops (El-Beltagi *et al.*, 2022). Water and nitrogen fertilizer are the two major consumable inputs in crop production in arid regions. Proper water management practices coupled with application of adequate amount of nitrogen fertilizer is crucial for optimizing crop production in arid regions (Gao *et al.*, 2023). Excessive water application without sufficient nitrogen can lead to nutrient leaching, while nitrogen application without adequate water results in limited nutrient uptake by plants. Several previous studies have noted the significant effect of combination of different doses of nitrogen and irrigation regimes on grain yield and yield parameters (Shirazi *et al.*, 2014, Al-Menaie *et al.*, 2021). However, the crop production in Kuwait is constrained by its unfavorable climatic and environmental conditions marked by drought, heat and salinity stresses and fragile ecosystems. In addition, the less percentage of arable land, less fertile soil with low organic matter content and limited water resources for irrigation drastically reduces the crop production in Kuwait. In this regard, adoption of improved soil management practices in animal feed production under optimized, water and fertilization regime could reduce the environmental impact of livestock farming, contribute to sustainable agricultural practices and result in cost savings

for farmers. Ultimately, it benefits animal health and productivity in agriculture. However, little information is available on the interactive effects between conservation agricultural practices and different irrigation and fertilization treatments on barley growth and yield. Thus, the study investigated the effect of tillage and mulching under different water and fertilizer application rates on barley under Kuwait's environmental conditions.

MATERIALS AND METHODS

Crop

The study was conducted at KISR Station for Research and Innovation-KSRI (29.3156°N, 47.8403°E), Kuwait at Kabd using barley which is a model crop as it is crucial to develop viable food producing agricultural systems that can be mastered by the local population. The barley variety Kuwait 2 was selected for the experiment owing to its high growth and yield performance as well as better adaptability to Kuwait's environmental conditions (Al-Menaie *et al.*, 2019).

Experimental design

Split-split plot randomized complete block design with three replications was used to conduct the experiment from November 2019 - March 2020, which involve a combination of the following different independent factors:

- Tillage (conventional versus minimum).
- Mulching using dried barley straw (mulch versus non-mulch).
- Irrigation (100% ET_c, 75% ET_c and 50% ET_c).
- Nitrogen (0 kg/ha, 50 kg/ha and 100 kg/ha).

Two forms of tillage (conventional and minimum) served as the main plots; whereas, mulching (mulching and non-mulching) formed the subplots. The sub-sub plots were occupied by different combinations of irrigation and nitrogen treatments. Each experimental plot of 3 m² size consisted of 1 replicate of barley under one of the treatments in 6 rows of 2.5 m in length with 20 cm in-row spacing. The individual as well as the interactive effects of the different soil, water and fertilizer management practices applied were studied using plant samples collected from each of the three replicates of each combination of treatments. The border rows were eliminated to avoid border effect and plant samples were collected from 1 m² area in each replicate at harvest period for determining plant height, number of plants per square meter, spike length, number of spikes per square meter, biomass yield, grain weight, harvest index and residue yield.

Irrigation and fertilization

A sprinkler irrigation system with an automatic timer was used to irrigate the experimental plots. The full irrigation volume was determined using estimates of evapotranspiration (ET) based on weather data and a crop coefficient. Daily weather data (maximum and minimum air temperature and relative humidity, average wind speed and total solar radiation) were used to calculate reference evapotranspiration (ET₀) using the well-established Penman-Monteith evapotranspiration method (Allen *et al.*, 1998). The 75% ET_c and 50% ET_c treatments were accomplished by taking

into account 75% and 50% of the time required for the full irrigation. Nitrogen, phosphorous and potassium fertilizers were used for fertilization. Phosphorous was applied in the form of triple superphosphate $[(Ca(H_2PO_4)_2 \cdot H_2O)]$ containing 43-44% P_2O_5 @ 150 kg P_2O_5 ha⁻¹ during land preparation stage. Potassium was added at the rate of 120 kg K_2O ha⁻¹ in the form of potassium sulfate (K_2SO_4) fertilizer (50% K_2O) as two equal doses at tillering and heading stages. Regular nitrogen in the form of urea $[(CO(NH_2)_2)]$ containing 46% N was applied at the rate of 0 kg/ha (control), 50 kg/ha and 100 kg/ha in 10 split applications starting after the emergence of seedling to just before heading. Split application of nitrogen fertilizer is a common local practice as the soil texture is sandy. One-time application of nitrogen fertilizer might lead to significant loss of fertilizer through leaching during daily irrigation practice.

Statistical analysis

Multifactor analysis of variance was performed to determine any significant difference in the mean values of the dependent variable under different irrigation as well as

nitrogen treatments using Statistical Package for Social Sciences (SPSS) software. Treatments displaying significant differences were subjected to Duncan's multiple range test (DMRT) for mean separation at a 95% confidence level.

RESULTS AND DISCUSSION

The study reported an interaction between tillage*mulch*irrigation*nitrogen. Therefore, the growth and yield performance of barley under different nitrogen treatments was analyzed under each combination of tillage, mulch and irrigation treatments as follows:

Conventional tillage with mulching under 100% ET_c irrigation

The biomass yield differed significantly ($p < 0.005$) between the three nitrogen treatments, wherein, the highest yield was noted with 100 kgN/ha followed by 50 and 0 kgN/ha. In contrast, plant height, number of plants per meter square, spike length, number of spikes per meter square, grain weight, harvest index and residue yield did not present any significant difference between the treatments (Table 1-8).

Table 1: Plant height (cm) under different soil and irrigation treatments to three different nitrogen treatments.

	CTM			CTNM			MTM			MTNM		
	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3
N1	71.5 ^a	70.5 ^a	65.5 ^a	66.5 ^a	73.5 ^a	48.0 ^a	72.5 ^a	80.0 ^b	48.5 ^a	73.0 ^b	78.0 ^b	49.0 ^a
N2	79.5 ^a	70.5 ^a	60.5 ^a	75.0 ^a	82.0 ^a	55.0 ^b	74.5 ^a	72.5 ^b	58.0 ^b	76.5 ^b	71.0 ^a	60.5 ^b
N3	74.0 ^a	65.0 ^b	65.5 ^a	66.0 ^a	75.0 ^a	57.5 ^b	86.0 ^b	57.5 ^a	56.5 ^b	63.5 ^a	70.5 ^a	54.5 ^{ab}

a,b,c: Mean values with different superscripts in each column were significantly different ($p \leq 0.05$)

N1, N2, N3: Nitrogen treatments (100, 50 and 0 kgN/ha); IR1, IR2, IR3: Irrigation treatments (100%, 75% and 50% ET_c), CTM: Conventional tillage with mulch, MTM: Minimum tillage with mulch; CTNM: Conventional tillage with no mulch; MTNM: Minimum tillage with no mulch.

Table 2: Number of plants/m² under different soil and irrigation treatments to three different nitrogen treatments.

	CTM			CTNM			MTM			MTNM		
	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3
N1	438 ^a	225 ^a	346 ^a	360 ^a	265 ^a	289 ^b	487 ^a	268 ^c	155 ^a	493 ^a	268 ^a	73 ^a
N2	432 ^a	225 ^a	263 ^a	411 ^a	235 ^a	253 ^a	521 ^a	246 ^b	274 ^a	535 ^a	273 ^a	170 ^b
N3	456 ^a	327 ^b	318 ^a	434 ^a	252 ^a	305 ^a	450 ^a	217 ^a	258 ^a	401 ^a	212 ^a	227 ^c

a,b,c: Mean values with different superscripts in each column were significantly different ($p \leq 0.05$).

N1, N2, N3: Nitrogen treatments (100, 50 and 0 kgN/ha); IR1, IR2, IR3: Irrigation treatments (100%, 75% and 50% ET_c), CTM: Conventional tillage with mulch, MTM: Minimum tillage with mulch; CTNM: Conventional Tillage with no mulch; MTNM: Minimum tillage with no mulch.

Table 3: Spike Length (cm) under different soil and irrigation treatments to three different nitrogen treatments.

	CTM			CTNM			MTM			MTNM		
	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3
N1	12.0 ^a	16.0 ^a	11.0 ^a	9.5 ^a	15.5 ^a	10.5 ^a	13.5 ^a	14.0 ^a	18.5 ^b	14.0 ^a	14.0 ^a	14.0 ^c
N2	13.0 ^a	16.0 ^a	12.0 ^a	9.5 ^a	14.0 ^a	15.5 ^b	13.5 ^a	17.0 ^a	13.5 ^a	14.0 ^a	16.0 ^{ab}	16.5 ^b
N3	10.5 ^a	12.0 ^a	12.0 ^a	12.5 ^b	13.5 ^a	14.5 ^b	12.0 ^a	12.5 ^a	14.0 ^a	14.5 ^a	19.0 ^a	17.0 ^b

a,b,c: Mean values with different superscripts in each column were significantly different ($p \leq 0.05$).

N1, N2, N3: Nitrogen treatments (100, 50 and 0 kgN/ha); IR1, IR2, IR3: Irrigation treatments (100%, 75% and 50% ET_c), CTM: Conventional tillage with mulch, MTM: Minimum tillage with mulch; CTNM: Conventional Tillage with no mulch; MTNM: Minimum tillage with no mulch.

Conventional tillage with mulching under 75% ET_c irrigation

The plant height ($p<.05$) and biomass yield ($p<.005$) varied significantly between the nitrogen treatments. The highest value for plant height was found in treatments with 0 kgN/ha followed by 50 and 100 kgN/ha. In contrast, biomass yield produced the highest value with 100 kgN/ha followed by 50 and 0 kgN/ha. The nitrogen treatments did not vary significantly the other parameters, such as the spike length, number of spikes per square meter, harvest index, residue yield and grain weight (Table 1-8).

Conventional tillage with mulching under 50% ET_c irrigation

The number of plants per square meter ($p<.005$) differed significantly between the nitrogen treatments and presented highest values with 0 kgN/ha. However, the plant height, number of spikes/m², residue yield, biomass yield, spike length, grain weight and harvest index did not differ between the nitrogen treatments (Table 1-8).

Conventional tillage without mulching under 100% ET_c irrigation

Spike length ($p<.05$) and number of spikes per square meter ($p<.05$) varied significantly between the nitrogen treatments; wherein, the highest value was recorded by 0 kgN/ha followed by 50 kgN/ha. For both biomass yield and residue yield, the highest values were noted with 100 kgN/ha without any significant difference from 50 kgN/ha. Other parameters such as plant height, number of plants per meter square, plant height, grain weight and harvest index were not affected significantly by the nitrogen treatments (Table 1-8).

Conventional tillage without mulching under 75% ET_c irrigation

The nitrogen treatments significantly affected the number of spikes per square meter ($p<.05$), which presented the highest performance with 50 kgN/ha. Similarly, grain weight varied significantly ($p<.05$) between the nitrogen treatments with the highest value under 100 kgN/ha. In contrast, the nitrogen treatments did not vary other parameters such as plant height, number of plants per square meter, spike length, biomass yield, harvest index and residue yield (Table 1-8).

Conventional tillage without mulching under 50% ET_c Irrigation

Plant height ($p<.05$), spike length ($p<.05$) and harvest index ($p<.05$) differed significantly between the nitrogen treatments. Interestingly, all of these parameters displayed higher values when no nitrogen was added in the plots. Plant height and spike length produced the highest values with 0 kgN/ha with no significant difference from 50 kgN/ha. Likewise, the harvest index was the highest with 100 kgN/ha without any significant difference from 0 kgN/ha. In contrast, biomass yield and grain weight did not differ significantly between the nitrogen treatments (Table 1-8).

Reduced tillage with mulching under 100% ET_c irrigation

The number of plants per square meter, spike length, number of spikes and grain weight did not differ between the nitrogen treatments. In contrast, plant height ($p<.01$) and harvest index ($p<.05$) presented a significant difference between the nitrogen treatments with higher values with 0 kgN/ha. Similarly, biomass yield as well as residue yield ($p<.005$)

Table 4: Number of spikes/m² under different soil and irrigation treatments to three different nitrogen treatments.

	CTM			CTNM			MTM			MTNM		
	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3
N1	256 ^a	139 ^a	128 ^b	203 ^a	175 ^a	77 ^a	302 ^a	177 ^a	135 ^a	309 ^a	121 ^a	24 ^a
N2	274 ^a	139 ^a	94 ^a	328 ^b	197 ^b	130 ^b	322 ^a	135 ^b	159 ^a	359 ^a	200 ^b	65 ^b
N3	275 ^a	169 ^a	167 ^c	340 ^b	172 ^a	207 ^c	375	169 ^a	150 ^a	369 ^a	146 ^a	242 ^c

a,b,c: Mean values with different superscripts in each column were significantly different ($p\leq0.05$).

NI, N2, N3: Nitrogen treatments (100, 50 and 0 kgN/ha); IR1, IR2, IR3: Irrigation treatments (100%, 75% and 50% ET_c), CTM: Conventional tillage with mulch, MTM: Minimum tillage with mulch; CTNM: Conventional Tillage with no mulch; MTNM: Minimum tillage with no mulch.

Table 5: Grain weight under different soil and irrigation treatments to three different nitrogen treatments.

	CTM			CTNM			MTM			MTNM		
	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3
N1	0.65 ^a	0.50 ^a	0.20 ^a	0.45 ^a	0.50 ^b	0.30 ^a	0.35 ^a	0.40 ^a	0.04 ^a	0.20 ^b	0.40 ^a	0.1
N2	0.75 ^a	0.60 ^a	0.15 ^a	0.60 ^a	0.20 ^a	0.15 ^a	0.75 ^a	0.70 ^b	0.25 ^a	0.50 ^b	0.55 ^a	0.1
N3	0.55 ^a	0.25 ^a	0.25 ^a	0.35 ^a	0.25 ^a	0.30 ^a	0.50 ^a	0.30 ^a	0.20 ^a	0.40 ^a	0.30 ^a	0.15

a,b,c: Mean values with different superscripts in each column were significantly different ($p\leq0.05$)

NI, N2, N3: Nitrogen treatments (100, 50 and 0 kgN/ha); IR1, IR2, IR3: Irrigation treatments (100%, 75% and 50% ET_c), CTM: Conventional tillage with mulch, MTM: Minimum tillage with mulch; CTNM: Conventional Tillage with no mulch; MTNM: Minimum tillage with no mulch.

varied significantly between the treatments producing the highest values with 100 kgN/ha (Table 1-8).

Reduced tillage with mulching under 75% ET_c irrigation

The nitrogen treatments significantly varied the plant height ($p < .05$), number of plants per square meter ($p < .01$) and grain weight ($p < .05$), with the highest values under 100 kgN/ha. Similarly, the number of spikes per square meter varied significantly between the treatments with 50 kgN/ha presenting the highest value. However, spike length, biomass yield, residue yield and harvest index did not differ significantly between the nitrogen treatments (Table 1-8).

Reduced tillage with mulching under 50% ET_c irrigation

Plant height differed significantly ($p < .05$) between three nitrogen treatments with the highest value under 50 kgN/ha. Spike length ($p < .01$) produced the highest values with 100 kgN/ha; whereas, residue yield ($p < .05$) and biomass yield ($p < .05$) presented the highest values with 0 kgN/ha followed by 50 kgN/ha. The parameters, namely, the number of plants per square meter, number of spikes per square meter and grain weight, did not vary significantly between the nitrogen treatments (Table 1-8).

Reduced tillage without mulching under 100% ET_c irrigation

The number of plants per square meter and spike length did not vary between the treatments under different nitrogen treatments. In contrast, plant height ($p < .005$), biomass yield ($p < .05$) and residue yield ($p < .005$) varied significantly between the treatments, with the highest values under 50 as well as 100 kgN/ha. Similarly, the harvest index ($p < .05$) varied between the treatments with the highest values under 0 and 50 kgN/ha (Table 1-8).

Reduced tillage without mulching under 75% ET_c irrigation

The plant height differed significantly ($p < .05$) between the treatments with the highest value under 100 kgN/ha. The spike length ($p < .05$) was the highest with 0 kgN/ha without any significant difference from 50 kgN/ha. The number of spikes per square meter ($p < .005$), biomass ($p < .05$) and residue yield ($p < .05$) varied significantly between the nitrogen treatments with the highest values under 50 kgN/ha. The parameters, namely, number of plants per square meter and grain weight, did not vary significantly between the nitrogen treatments (Table 1-8).

Table 6: Harvest index under different soil and irrigation treatments to three different nitrogen treatments.

	CTM			CTNM			MTM			MTNM		
	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3
N1	23.97 ^a	23.81 ^a	8.7 ^a	17.26 ^a	24.40 ^a	23.08 ^b	12.66 ^a	16.52 ^a	20.00 ^a	9.11 ^a	16.02 ^a	100 ^a
N2	28.84 ^a	28.57 ^a	7.38 ^a	22.96 ^a	13.57 ^a	8.33 ^a	37.55 ^b	36.84 ^a	22.72 ^a	21.74 ^{ab}	20.07 ^a	5.56 ^a
N3	26.66 ^a	13.89 ^a	19.05 ^a	18.42 ^a	13.33 ^a	17.50 ^{ab}	37.08 ^b	25.17 ^a	11.27 ^a	41.66 ^b	21.87 ^a	10.71 ^a

a,b,c: Mean values with different superscripts in each column were significantly different ($p \leq 0.05$)

NI, N2, N3: Nitrogen treatments (100, 50 and 0 kgN/ha); IR1, IR2, IR3: Irrigation treatments (100%, 75% and 50% ET_c), CTM: Conventional tillage with mulch, MTM: Minimum tillage with mulch; CTNM: Conventional Tillage with no mulch; MTNM: Minimum tillage with no mulch.

Table 7: Residue yield under different soil and irrigation treatments to three different nitrogen treatments.

	CTM			CTNM			MTM			MTNM		
	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3
N1	2.06 ^a	1.60 ^a	2.10 ^b	2.15 ^b	1.55 ^a	1.00 ^a	2.40 ^b	2.00 ^a	0.16 ^a	2.00 ^b	2.10 ^b	0.10 ^a
N2	1.85 ^a	1.50 ^a	1.90 ^b	2.00 ^b	1.30 ^a	1.65 ^a	1.25 ^a	1.20 ^a	0.85 ^b	1.80 ^b	2.15 ^b	1.70 ^c
N3	1.50 ^a	1.55 ^a	1.05 ^a	1.55 ^a	1.65 ^a	1.45 ^a	0.85 ^a	0.90 ^a	1.55 ^c	0.60 ^a	1.10 ^a	1.25 ^b

a,b,c: Mean values with different superscripts in each column were significantly different ($p \leq 0.05$).

NI, N2, N3: Nitrogen treatments (100, 50 and 0 kgN/ha); IR1, IR2, IR3: Irrigation treatments (100%, 75% and 50% ET_c), CTM: Conventional tillage with mulch, MTM: Minimum tillage with mulch; CTNM: Conventional Tillage with no mulch; MTNM: Minimum tillage with no mulch.

Table 8: Biomass yield under different soil and irrigation treatments to three different nitrogen treatments.

	CTM			CTNM			MTM			MTNM		
	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3	IR1	IR2	IR3
N1	2.71 ^c	2.10 ^b	2.30 ^b	2.60 ^b	2.05 ^a	1.30 ^a	2.75 ^c	2.40 ^a	0.10 ^a	2.20 ^b	2.50 ^b	0.10 ^a
N2	2.60 ^b	2.10 ^b	2.05 ^b	2.60 ^b	1.50 ^a	1.80 ^a	2.00 ^b	1.90 ^a	1.10 ^b	2.30 ^b	2.70 ^b	1.80 ^a
N3	2.05 ^a	1.80 ^a	1.30 ^a	1.90 ^a	1.90 ^a	1.75 ^a	1.35 ^a	1.20 ^a	1.75 ^a	1.0 ^a	1.40 ^a	1.40 ^a

a,b,c: Mean values with different superscripts in each column were significantly different ($p \leq 0.05$).

NI, N2, N3: Nitrogen treatments (100, 50 and 0 kgN/ha); IR1, IR2, IR3: Irrigation treatments (100%, 75% and 50% ET_c), CTM: Conventional tillage with mulch, MTM: Minimum tillage with mulch; CTNM: Conventional Tillage with no mulch; MTNM: Minimum tillage with no mulch.

Reduced tillage without mulching under 50% ET_c irrigation

The plant height and residue yield ($p < .05$) produced the highest value with 50 kgN/ha followed by 0 kgN/ha. The spike length ($p < .005$) displayed the highest values with 0 kgN/ha, followed by 50 kgN/ha; whereas, the harvest index ($p < .05$) was the highest with 100 kgN/ha. The parameters, namely, biomass yield and grain weight, did not differ significantly between the nitrogen treatments (Table 1-8).

In arid land agriculture, water and fertilization are two major limiting factors that influence crop production. With the view to study the impact of conservational agricultural practices on improving barley production sustainably, the selected barley variety was subjected to three different irrigation (100% ET_c, 75% ET_c, 50% ET_c) and fertilization treatments (100 kgN/ha, 50 kgN/ha and 0 kgN/ha) under different combination of tillage and mulching. Taking into consideration all the combination of treatments, the highest biomass yield and residue yield was noted under minimum tillage with mulching under 100% ET_c irrigation with 100 kgN/ha. In case of grain yield, minimum as well as conventional tillage with mulching under 100% ET_c irrigation and 50 kgN/ha produced the highest value. Other parameters, such as plant height and number of spikes per square meter also exhibited the highest yield with minimum tillage and mulching under 100% ET_c irrigation.

The results agreed with those of several previous studies, which recorded the positive impact of conservation agricultural practices, such as minimum tillage and mulching, on the plant growth and yield. A previous study conducted by Zamir *et al.* (2013) in maize reported improved grain yield, plant height and number of cobs per plant under zero tillage and straw mulching in maize. A similar study conducted in semi-arid regions of Algeria, noted increased spike density, harvest index and grain yield under no tillage system (Chouter *et al.*, 2022). The increased availability of soil residues under reduced tillage in turn increase the soil moisture content and reduces water evaporation in comparison to conventional tillage. Another study conducted on chick pea revealed higher growth, yield and nutrient uptake under mulching (Kumar and Angadi, 2016). The increased availability of moisture and nutrients coupled with increased utilization efficiency of these resources by the plants could eventually increase the thousand kernel weight and thus grain yield under minimum tillage and mulching. Similarly, several other previous studies reported that mulching treatment caused a significant increase in the grain yield as compared to the non-mulching treatment (Tolk *et al.*, 1999; Khan *et al.*, 2009). Likewise, increased plant height, number of grains per spike and grain weight were noted under zero tillage and mulching in another study (Albuquerque *et al.*, 2001; Shirani *et al.*, 2002). In contrast, another study noted highest plant height, fresh weight and dry weight with conventional tillage than no tillage practices (Roy *et al.*, 2018). Several previous studies have concluded that mulching and tillage gave the maximum plant height, grain yield and biological

yield (Pervez *et al.*, 2009; Vetsch *et al.*, 2002). Improved biomass yield could be attributed to the increased plant height, more number of plant leaves and more crop growth rate.

CONCLUSION

The study on the interactive effect of tillage, mulching, different irrigation and fertilizer application rates, on barley growth and yield performance noted positive effects of conservation agricultural practices in barley production systems. The interaction noted between tillage, mulching, irrigation and fertilization application rates revealed highest biomass yield and residue yield under minimum tillage with mulching under 100% ET_c irrigation and 100 kgN/ha. In case of grain yield, minimum as well as conventional tillage with mulching under 100% ET_c irrigation and 50 kgN/ha produced the highest value. Other parameters, such as plant height, number of plants per square meter, number of spikes per square meter and harvest index, also exhibited the highest yield with minimum tillage and mulching under 100% ET_c irrigation. Suitable tillage and mulching practice under optimum irrigation and fertilization regime improves yields while conserving resources. Thus the synergistic use of mulching and suitable tillage practices offers multifaceted benefits that positively influences barley production, promoting sustainable agriculture. Follow-up research is crucial to facilitate vertical and horizontal technology transfer to specific end-users ensuring technological advancement in the field of soil, water and fertilizer management practices in agriculture sector of Kuwait.

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Conflict of interest

The authors declare no conflict of interest.

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